Study on Auditory Impressions of Train Departure Sign Sounds

電車の発車サイン音に関する聴感印象の調査

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1. Introduction

1.1. Research Background

In Japan, train departures are commonly marked by various types of sound. The most common ones are electric bells and melodic jingles (called bell and melody onwards). Departure sounds can cause discomfort and stress to passengers, especially those who are sensitive to sound. However, a guideline for broadcasting these sounds is not yet standardized.

1.2. Objectives

This research aims to improve acoustic environments in train stations from the aspect of departure signal sounds. Specifically, this study will describe the current actual sound characteristics, examine the effect of acoustic features towards impressions, investigate the change in impressions under noisy conditions, and search impression distinctions from people with different sensitivity.

1.3. Study Approach

This study used the model proposed by Marquis-Favre *et al.* as the research base. They stated that there are two factors which influence impressions toward sounds: acoustic factors and non-acoustic factors. Acoustic factors cover physical, sound quality features, and context, while non-acoustic factors cover attitude, socio-demographic, and situational aspects. Additionally, there is one more factor that was developed from the context aspect in acoustic factor, which is the presence of multiple sounds or ambient noise [1].

2. Research Outline

2.1. Sound Feature Analysis

A total of 40 sounds recorded at train stations in Tokyo had their background noise removed. Then, the sounds are normalized to 60 dB(A). Nine acoustic parameters were extracted from the sign sounds: loudness level (LN), percentile loudness (N5), sharpness (S), roughness (R), modulation frequency (F_{Mod}), tempo, mode, average pitch (F_{Ave}), and pitch standard deviation (F_{SD}). Cluster analysis was then conducted on both bell and melody respectively to find feature similarities. A total of 5 and 6 clusters were obtained for bells and melodies, respectively.

Table 1. Features of sounds samples at 60 dB.

Sound	Type	LN [phon]	N5 [sone]	S [acum]	R [asper]	Fmod [Hz]	Tempo [BPM]	Mode	Fave [Cent]	F_{SD} [Cent]
B1	Bell	64.3	5.0	1.01	0.11	22	-	-	1118	72
B2	Bell	70.4	8.2	1.06	0.06	22	-	-	402	115
B3	Bell	63.7	5.3	1.19	0.01	0	-	-	1074	1
B4	Bell	69.9	7.0	1.49	0.11	16	-	-	1170	91
B5	Bell	71.2	8.4	1.69	0.09	0	-	-	414	161
M1	Melody	75.1	12.7	1.83	0.11	-	149	Minor	629	144
M2	Melody	73.3	9.7	1.28	0.05	-	119	Major	888	688
M3	Melody	73.2	9.6	1.33	0.06	-	117	Minor	1195	706
M4	Melody	77.4	12.7	1.62	0.03	-	122	Minor	-27	775
M5	Melody	79.0	15.4	1.61	0.06	-	112	Major	-704	1335
M6	Melody	71.3	9.0	1.17	0.07	-	145	Major	703	558

2.2 Sound Evaluation Experiment

One sample from each cluster was selected for the listening experiment. Table 1 shows the characteristics of the samples chosen from each cluster. Sounds were presented inside the anechoic chamber at 60, 70, and 80 dB. Semantic differential scale containing nine pairs of adjective divided into “timbre” and “mood” categories was used to evaluate the sounds. A total of 23 participants (13 males, 10 females) joined the experiment.

2.3 Ambient Noise Effect Experiment

Bell and melody sounds were presented together with a recorded background noise consists of train engine sound in a stationary condition. The sound was then normalized to 65 dB and 75 dB which is considered as common station noise levels. Signal-to-noise ratio (SNR) was used as the controlled variable ranging from +0 dB to +20 dB with 5 dB difference between each step. The evaluation was made using semantic differential scale containing 11 pairs of adjectives divided into “timbre”, “mood” and “effectiveness” category. A total of 21 participants (11 males, 10 females) joined the experiment.

2.4 Human Factor Analysis

Three demographic factors were analyzed for participants from each experiment. The considered factors include gender, nationality, and hearing sensitivity. This analysis aims to see the difference between each group.

3. Results and Discussion

3.1 Acoustic Features and Impressions

- <u>Overall Impressions</u>

Figure 1 shows the average scores for bells

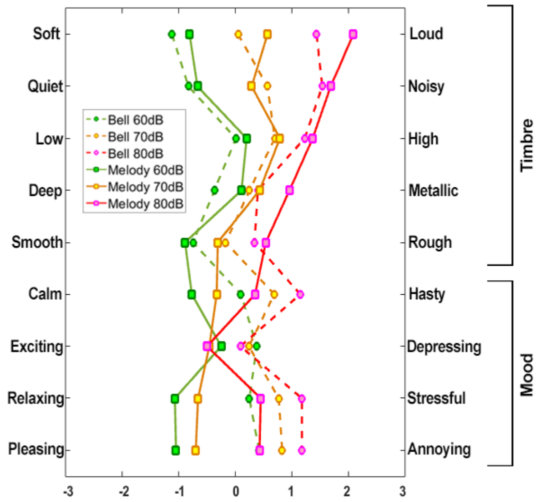

Figure 1. Overall impressions of departure sign sounds.

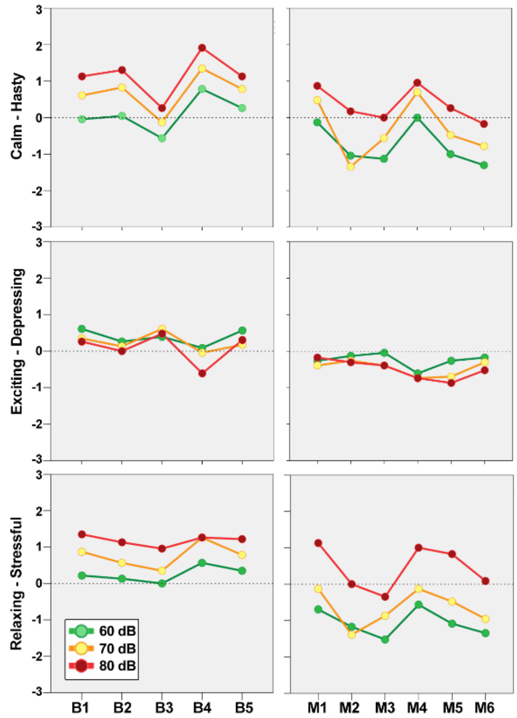

Figure 2. Comparison of impressions between samples.

Table 2. Comparison of R^2 value between predictors.

	Auditory Impressions	Laeq	LN	Laeq x R or S	Laeq x R or S Model
		Coefficient of Determination (R^2)			
Bell	Calm - Hasty	0.44	0.64	0.80	$-2.28 + (0.031 \times LAeq) + (7.3 \times R)$
	Exciting - Depressing	0.16	0.29	0.36	$1.01 - (0.007 \times LAeq) - (2.6 \times R)$
	Relaxing - Stressful	0.74	0.76	0.90	$-2.18 + (0.037 \times LAeq) + (3.3 \times R)$
	Pleasing - Annoying	0.85	0.66	0.88	$-1.76 + (0.035 \times LAeq) + (1.1 \times R)$
Melody	Calm - Hasty	0.40	0.53	0.78	$-6.79 + (0.049 \times LAeq) + (2.1 \times S)$
	Exciting - Depressing	0.20	0.39	0.26	$0.83 - (0.012 \times LAeq) - (0.3 \times S)$
	Relaxing - Stressful	0.61	0.75	0.85	$-7.96 + (0.070 \times LAeq) + (1.7 \times S)$
	Pleasing - Annoying	0.62	0.75	0.82	$-7.64 + (0.069 \times LAeq) + (1.6 \times S)$

and melodies at each sound level. Overall, as the sound level gets louder, the scores tend to be higher, except for "exciting-depressing". Regarding timbre-related terms, melodies have higher scores than bells at the same level, whereas the opposite relationship is seen regarding mood-related terms. It is notable that melodies are perceived as louder than bells, but give more positive moods such as "calm", "relaxing", and "pleasing".

- <u>Difference Between Samples</u>

Figure 2 shows the average scores of three mood-related terms for each sound sample. "Exciting-depressing" scores are around neutral regardless of the sound level and sample. It is notable that stressfulness of bells has minimum difference between sample sounds and seem to be influenced only by volume. On the other hand, differences can be seen on melody stressfulness of bell which is very similar to hastiness response. This is considered due to the difference in loudness level. The difference in hastiness impression for bells is mostly influenced by their roughness and loudness level.

- <u>Discomfort Prediction</u>

Table 2 presents the comparison of predictors and multiple regression models based on factors that are not collinear with each other. Statistical tests show that combination of volume and roughness is considered appropriate to predict bells while the combination of volume and sharpness is suitable for melody sounds.

3.2 Ambient Noise and Impressions

- <u>Comparison Between Ambient Conditions</u>

Figure 3 shows the average value for both melody and bell sounds at 80 dB under different listening conditions. It was found that sound at the same level will receive lower scores if the ambient noise gets louder. The tendency in which melody is perceived louder but less stressful still applies regardless the ambient noise level.

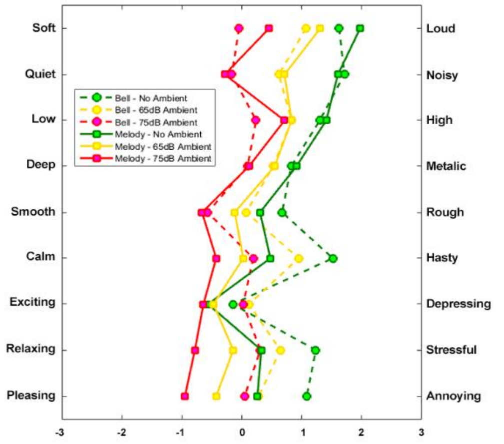

Figure 3. Comparison between ambient conditions.

- <u>High Discomfort and Audibility Percentage</u>

Figure 4 and Figure 5 show the percentage of "highly annoying", "highly stressful", "highly inaudible" and "highly unnoticeable" response for both sounds at two different conditions. Both sounds are considered to be audible from SNR +5 dB and above. However, at SNR +15 dB and +20 dB, there is a tendency of highly annoyance and stress. Therefore SNR between +5 dB and +10 dB is considered as the most appropriate. It is notable that at lower SNR, bells are deemed to be less audible than melodies, while at higher SNR the former is more annoying than the latter.

As rule of thumb, the most effective volume to broadcast both bell and melody lies between 70 dB to 85 dB of volume. This result shows similarity with [2] on melodies maximum value. Compared to the findings in [3], the actual condition in Tokyo exceeds these range values for bell sounds where the average of bells are played around 89 dB. On the other hand, the average of melodies is around 81 dB which is between the effective range. In conclusion, the actual sound level condition of train departure bells can be considered inappropriate.

3.3 Human Factors and Impressions

Table 3 shows the results from five-way analysis of variance between volume, sound samples, and human factors on auditory impressions for both bell and melody from the first listening experiment. Volume and sound samples influenced almost all impressions for both sounds. There is less influence caused by demographic factors on melody sounds than on bell sounds. Nationality difference has an effect on stressful impression on bell sounds which is likely due to the difference in familiarity towards bells. Socio-demographic factors show no significant effect on stressful and annoyance impressions. It is notable that people who are not used to hearing bell sounds are likely to get annoyed.

4. Conclusion

This study had examined the auditory impressions toward train departure sign sounds. It was found that sound volume highly influences annoyance of bell and melody. Also, it was confirmed that bell tend to be considered more annoying than melody. Actual condition of departure bells in Tokyo is also considered too loud, compared to the findings in this study. In the current study, the effect of several other factors such as duration and situational factors were not considered. Therefore, this approach might be suitable for future research.

References: [1] Marquis-Favre *et al.*, Acta Acustica, 91. 626-642. (2005). [2] 濱村他, 騒音制御工学会秋季. 57-60. (2013). [3] 亀田他, 東京大学 (卒論), (2016).

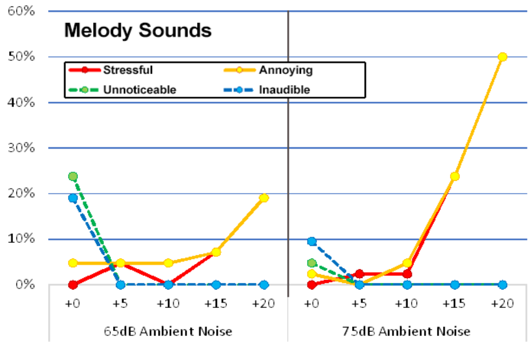

Figure 4. "Highly" percentage of melody sounds

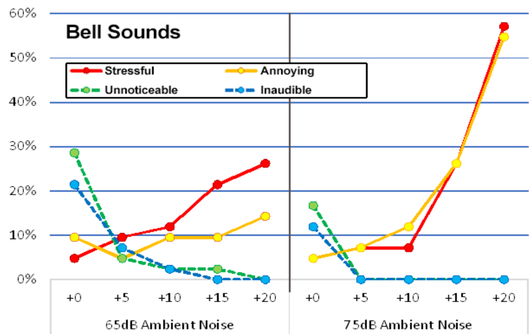

Figure 5. "Highly" percentage of bell sounds

Table 3. Five-way ANOVA of volume, type, and human factor on auditory impressions from experiment 1.

	Factors	soft - loud	quiet - noisy	low - high	deep - metallic	smooth - rough	calm - hasty	exciting - depressing	relaxing - stressful	pleasing - annoying
Bell	Laeq	**	**	**	**	**	**		**	**
	Sound Type	**	**	**	**	**	**	**		
	Gender	*	*	**	**		*			*
	Nationality	**	**				**	**	**	**
	Sensitivity						**			
Melody	Laeq	**	**	**	**	**	**		**	**
	Sound Type	**	**	**	**	**	**	*	**	**
	Gender			*						
	Nationality						**	**		
	Sensitivity	*	*		*	**				

** : p ≤ 1% * : p ≤ 5%