MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Effect of spatial separation between traffic noise and water sound on soundscape assessment

Hong, Joo-Young[1]
Lam, Bhan[2]
Ong, Zhen-Ting[3]
Gan, Woon-Seng[4]

School of Electrical & Electronic Engineering, Nanyang Technological University, 639798, Singapore

Feng, Jing[5]
Tan, Sze-Tiong[6]

Building & Research Institute, Housing & Development Board, 738973, Singapore

ABSTRACT

This study aims to examine the effect of the spatial separation and signal-to-noise ratio (SNR) between target traffic noise and water sound on soundscape assessment. An in situ audio-visual recording of a water fountain was augmented with an audio recording of a busy expressway for the laboratory test. The combined acoustic stimuli (traffic noise and water sound) were generated at five azimuths: water sound co-located with the traffic (0°) or symmetrically separated by ±45°, ±90°, ±135°, or 180°. In addition, the water sound presented at two SNRs (-3 and 3 dB). For audio-visual congruency, the viewpoint of the fountain video in each stimulus was shifted by the same azimuths (location of traffic is fixed). Participants experienced the audio-visual stimuli through a multi-channel loudspeaker system and a head-mounted display. The participants were asked to evaluate the perceived loudness of noise and overall soundscape quality of each stimulus. Results revealed that the effect of azimuth separation was significant in both perceived loudness of noise and overall soundscape quality. Meanwhile, the effect of SNR was only significant on the perceived loudness of noise.

Keywords: Soundscape, Spatial Audio, Virtual Reality
I-INCE Classification of Subject Number: 63; 74; 76; 79

[1] jyhong@ntu.edu.sg
[2] blam002@e.ntu.edu.sg
[3] ztong@ntu.edu.sg
[4] ewsgan@ntu.edu.sg
[5] feng_jing@hdb.gov.sg
[6] tan_sze_tiong@hdb.gov.sg

1. INTRODUCTION

Many studies provide clear evidence that pleasant water sounds can reduce the perceived loudness of traffic noise and improve the overall soundscape quality [1–4]. However, most of the previous studies assumed that target noise and water feature were co-located and examine masking effect of water sounds by varying signal-to-noise ratio between a water sound and a target noise, while paying little attention to the spatial separation between the target noise and the water feature. However, the assumption that at target noise and masker is co-located is limited in representing the real scenarios because sound sources are placed in three-dimensional space [5]. The masking effect could be dependent on the spatial separation of the target and masker. Spatially separated target and masker may not be effective as much as collocated ones. This phenomenon is explained by spatial release from masking (SRM) that detection of the target mask is enhanced if the target and masker are spatially distinct [6–9]. This implies that spatial separation between a target noise and a water sound may affect soundscape assessment. Therefore, it is necessary to investigate the effect of the spatial separation between target noise and water fountain on soundscape assessment. In this context, this study aims to explore the perceived masking efficacy of traffic noise by introducing a water fountain sound at different spatial orientations through a laboratory experiment.

2. METHOD

2.1 Participants

In total, twenty-three participants (13 males and 10 females) with normal-hearing were recruited for this study. The study was approved by the institutional review board of Nanyang Technological University (IRB-2017-07-025).

2.2 Stimuli

An omni-directional audio-visual recording of a water fountain was conducted at a distance of 4 m away from a fountain with a spherical panoramic camera (Garmin VIRB 360 Action Camera, USA) and an ambisonic microphone (Sennheiser AMBEO VR 3D Microphone, Germany) as shown in Figure 1. The video camera and microphone were placed at a height of 1.5 m from the ground. As a targeted noise, road traffic sound was also recorded at a distance of 40 m from an expressway (2 × 4 lanes) using the same ambisonic microphone. For the laboratory experiment, 10-s audio-visual samples of a water fountain were created. In addition, 10-s traffic sound was excerpted from the traffic noise of the expressway.

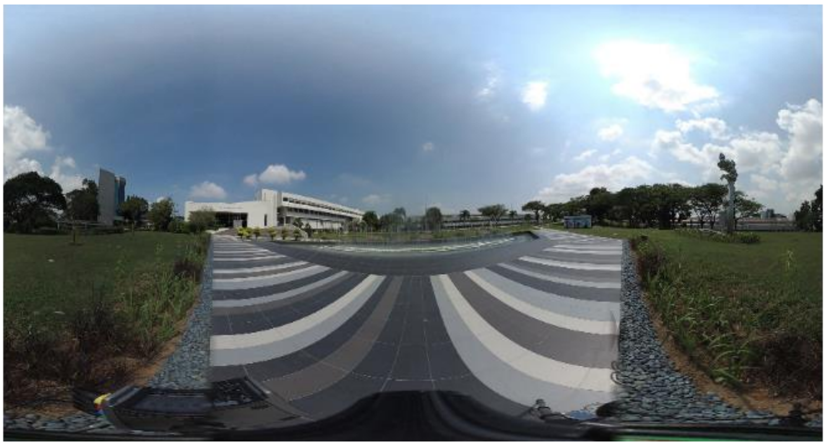

Figure 1. Equirectangular panoramic photo from the spherical video of the water fountain

2.3 Experimental design

In this study, a within-subject design was employed with two independent variables: two SNR (-3 dB and 3 dB) and five spatial configurations of azimuth angle (0°, ±45°, ±90°, ±135°, or 180°). The target traffic noise was set to 65 dBA, while the water fountain sounds were varied at 62 dBA or 68 dBA. Regarding the spatial configuration of the traffic and water sounds, as shown Figure 2(a), the traffic sound was located at 0° and the water sound was generated at five azimuths: 0° or symmetrically separated by ±45°, ±90°, ±135°, or 180°. For audio-visual congruency, the viewpoint of the fountain video in each stimulus was shifted by the same azimuths (location of traffic is fixed) as depicted in Figure 2(b). The audio-visual stimuli through a twelve-channel loudspeaker system and a head-mounted display (Pimax 4K VR, China) as shown in Figure 3. In total, 10 the combined audio-visual stimuli (the target traffic noise and water sound) were created for the test.

The participants were asked to evaluate the perceived loudness of noise (PLN) and overall soundscape quality (OSQ) of each stimulus. PLN was assessed with the method of magnitude estimation. The participants entered their magnitude estimates of the target traffic noise in the combined stimuli based on the reference sound (traffic noise at 65 dBA). The magnitude of the reference was instructed to '100'. Overall soundscape quality was evaluated using an 11-point rating scale (0: extremely unpleasant, 10: extremely pleasant).

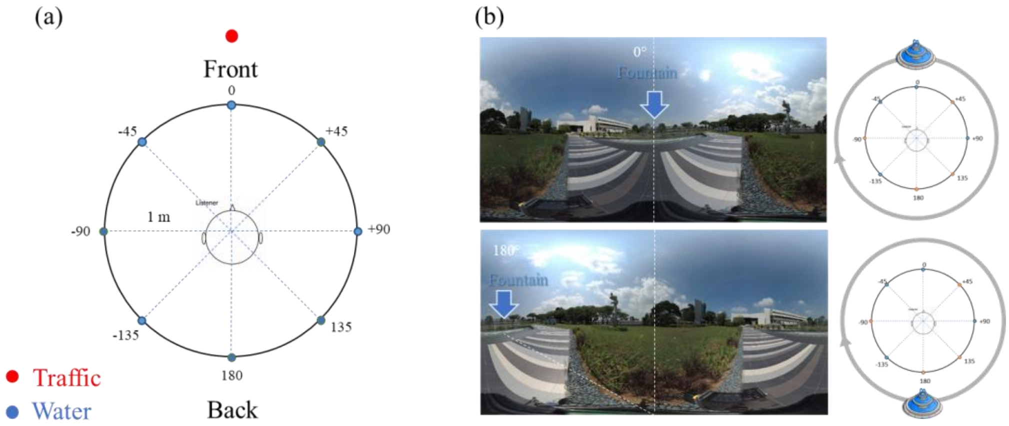

Figure 2. Schematic illustration of the experimental design: (a) azimuth separation between traffic noise (b)

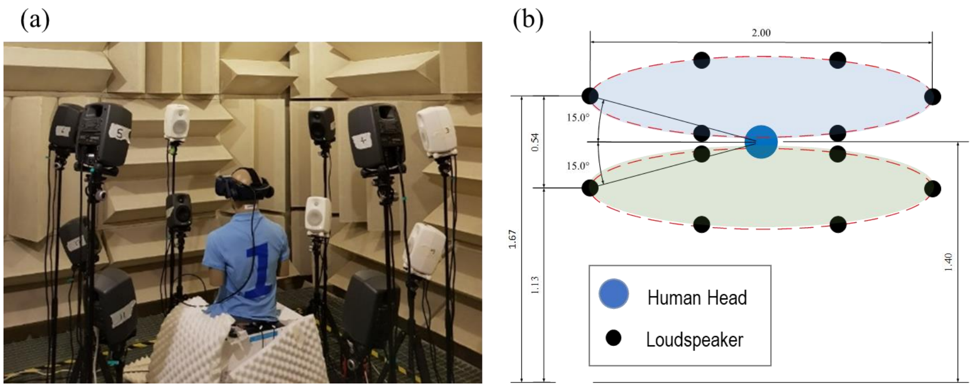

Figure 3. Loudspeaker array configuration: (a) photograph of the system in an anechoic chamber and (b) the loudspeaker configuration

2.4 Data analysis

Two-way repeated measure (RM) analysis of variance (ANOVA) was conducted to investigate the within-subjects effects of the SNR and azimuth separation on PLN and OSQ. The assumption of sphericity was tested using Mauchly's test of sphericity. When the assumption of sphericity was violated, the Greenhouse–Geisser correction was applied. Bonferroni adjustment was applied for post-hoc comparisons in RM ANOVA.

3. RESULTS

3.1 Perceived loudness of noise

The mean magnitude estimate values of PLN for all stimuli are plotted in terms of spatial separations and SNRs in Figure 4. Compared with the PLN of the target traffic noise, adding water fountain sound reduced the PLN across the five azimuth angles. The mean PLN values tended to increase as spatial separation increased. The RM ANOVA results showed that the main effects of SNR ($p < 0.01$) and spatial separation ($p < 0.05$) were statistically significant. SNR of 3 dB exhibited a greater reduction in PLN than that of -3 dB. Regarding the spatial separation, the post-hoc test revealed that a statistically significant difference in PLN was found between 0° and 135°. The interaction between SNR and spatial separation was not found.

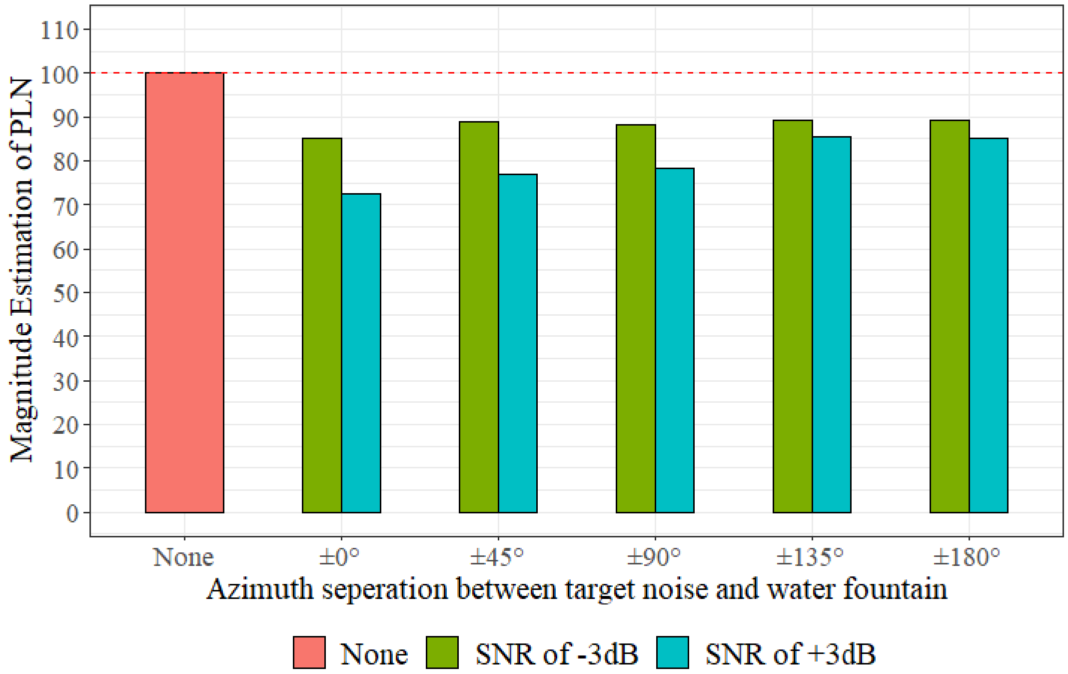

Figure 4. Mean values of PLN as a function of azimuth separations between the target noise and water fountain sound at two different SNRs.

3.2 Overall soundscape quality

Mean rating scores of OSQ in terms of SNR are presented as a function of azimuth separations in Figure 5. RM ANOVA results revealed that introducing pleasant water sound significantly increased the mean rating score of OSQ across the spatial separations compared to that of noise-alone cases ($p < 0.001$). Specifically, statistically significant differences were found from azimuth separation of 135° and 180° ($p < 0.05$). However, there were no significant differences in OSQ between SNRs of -3 dB and 3 dB. The interaction effect between SNR and spatial separation was not statistically significant.

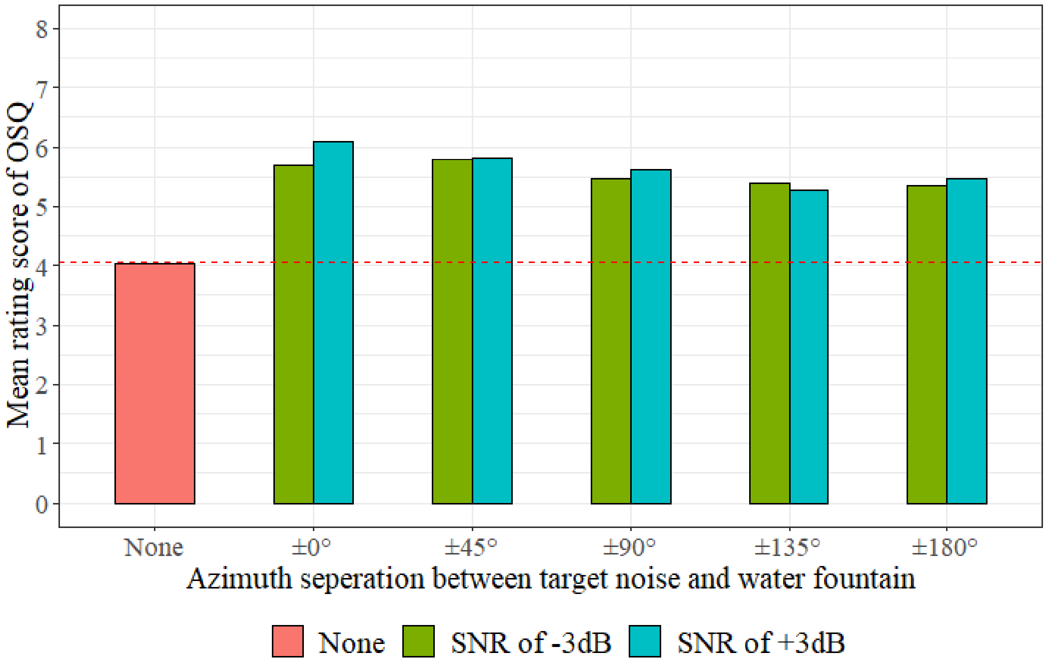

Figure 5. Mean values of OSQ as a function of azimuth separations between the target noise and water fountain sound at two different SNRs.

4. CONCLUSIONS

The effect of the spatial separation and SNR between target traffic noise and water sound on perceived loudness of noise and soundscape quality were examined through a laboratory experiment. The results showed that augmenting pleasant water sounds could decrease perceived loudness of the target noise and enhance overall soundscape quality. The effect of azimuth separation was significant in both perceived loudness of noise and soundscape quality. Perceived loudness reduction and enhancement of soundscape quality were the greatest when the target traffic noise and water sound were co-located, while the effects of water fountain sound became relatively smaller as the spatial separation between the noise and water sound became bigger. This indicates that the effect of SRM on soundscape assessment is significant. The SNR of 3 dB exhibited a larger reduction in perceived loudness reduction than the SNR of – 3 dB, whereas there were no significant differences in assessment of soundscape quality between the two SNRs. The findings of this study imply that soundscape designers should consider the location of a water fountain to exhibit the best effect of the target noise regarding perceived noise reduction and soundscape quality.

5. ACKNOWLEDGEMENTS

This material is based on research/work supported by the Singapore Ministry of National Development and National Research Foundation under L2 NIC Award No.: L2NICCFP2-546 2015-5. Joo-Young Hong is currently supported by the 2017 Lee Kuan Yew Postdoctoral Fellowship (Grant no. 50025000).

6. REFERENCES

[1] J.Y. Hong, J.Y. Jeon, Designing sound and visual components for enhancement of urban soundscapes., J. Acoust. Soc. Am. 134 (2013) 2026–36. doi:10.1121/1.4817924.

[2] M. Rådsten Ekman, P. Lundén, M.E. Nilsson, Similarity and pleasantness

assessments of water-fountain sounds recorded in urban public spaces, J. Acoust. Soc. Am. 138 (2015) 3043–3052. doi:10.1121/1.4934956.
[3] L. Galbrun, T.T. Ali, Acoustical and perceptual assessment of water sounds and their use over road traffic noise, J. Acoust. Soc. Am. 133 (2013) 227–237. doi:10.1121/1.4770242.
[4] M.E. Nilsson, J. Alvarsson, M. Rådsten-Ekman, K. Bolin, Auditory masking of wanted and unwanted sounds in a city park, Noise Control Eng. J. 58 (2010) 524. doi:10.3397/1.3484182.
[5] J.Y. Hong, J. He, B. Lam, R. Gupta, W.-S. Gan, Spatial Audio for Soundscape Design: Recording and Reproduction, Appl. Sci. 7 (2017) 1–21. doi:10.3390/app7060627.
[6] A. Ihlefeld, B. Shinn-Cunningham, Spatial release from energetic and informational masking in a selective speech identification task, J. Acoust. Soc. Am. 123 (2008) 4369–4379. doi:10.1121/1.2904826.
[7] A. Westermann, J.M. Buchholz, The influence of informational masking in reverberant, multi-talker environments, J. Acoust. Soc. Am. 138 (2015) 584–593. doi:10.1121/1.4923449.
[8] N.K. Srinivasan, K.M. Jakien, F.J. Gallun, Release from masking for small spatial separations: Effects of age and hearing loss, J. Acoust. Soc. Am. 140 (2016) EL73-EL78. doi:10.1121/1.4954386.
[9] D. Oberfeld, P. Stahn, M. Kuta, Binaural release from masking in forward-masked intensity discrimination: Evidence for effects of selective attention, Hear. Res. 294 (2012) 1–9. doi:10.1016/j.heares.2012.09.004.