Applied Acoustics 135 (2018) 60–69

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Perceptual assessment of indoor water sounds over environmental noise through windows

Wonyoung Yang[a,*], Hyeun Jun Moon[a], Myung-Jun Kim[b]

[a] Department of Architectural Engineering, Dankook University, Yongin 16890, Republic of Korea
[b] Department of Architectural Engineering, University of Seoul, Seoul 02504, Republic of Korea

ARTICLE INFO

Keywords:
Noise perception
Indoor water sounds
Indoor noise
Natural ventilation

ABSTRACT

Indoor water sounds were examined in terms of perceptual enhancement of environmental noise through openings for natural ventilation. An experiment was conducted using a simple indoor water fountain system with forty participants (18 women and 22 men) aged between 19 and 27 in an environmental chamber. The indoor water sound levels were varied from 35.8 dBA to 59.8 dBA. Environmental noises transmitted through windows in the living rooms of actual residences were measured and classified into traffic and railway noises and their levels were between 43.0 dBA and 62.1 dBA.

The subjective judgment obtained from laboratory experiments showed that the introduction of water sounds resulted in an improvement of environmental noise entering through windows according to water sound level in four psychoacoustical characteristics, where the perception of annoyance reduced and that of pleasantness, calmness and naturalness increased. Pleasantness was the most sensitive characteristic, and noisiness and loudness were the least sensitive characteristics describing the indoor water effects among the six psychoacoustical characteristics used. In terms of gender difference, it was found that women were more perceptive to the introduction of water sounds than men in the parameters of noisiness, loudness and annoyance.

1. Introduction

It has been demonstrated that natural ventilation plays a key role in sustainable architecture for improving indoor thermal comfort, reducing energy requirements, and mitigating urban heat islands [1]. However, in dense urban areas with high levels of environmental noise such as vehicles and construction, natural ventilation is accompanied by increased indoor noise levels [2]. Therefore, the ability to open windows for natural ventilation can be limited by excessive outdoor noise. Various noise control engineering methods for reducing the ingress of urban noise through natural ventilation openings have been developed [2–5]. However, these noise control engineering methods were often not economically feasible or mobile. An alternative approach has been presented to improve the quality of the indoor acoustics by introducing desirable sounds or other sensations to mask or distract attention from outdoor environmental noise; this approach was validated in an urban soundscape [6–10]. However, only a few studies have been performed on perceptual methods to enhance noise perception. Ma and Nie [11] found that both improving the lighting conditions and creating a reasonable combination of color and brightness were helpful for enhancing the perception of noise in an indoor environment. Leung et al. [12] attempted to develop a statistical model in which a mixture of water and road traffic sounds were rated in a home environment according to a noise annoyance rating, while considering the effects of the visual environment. They also found that water sounds accompanied with visual scenery were effective in reducing the noise annoyance rating using video clips and sound scripts.

The preferred acoustical characteristics of water sounds have been studied for soundscape enhancement. The temporal variation and spectral envelope of water sounds have been investigated in laboratory and field experiments. Watts et al. [13] assessed the perceived tranquility of traffic noise in the presence of various water sounds which were produced by water falling onto water, gravel, bricks, small boulders and combinations of the above (at a weir height of 30 cm and a weir width of 10 cm). The most preferred sounds were water falling onto a small boulder, small boulders with more cavities and a boulder mound with one flatter boulder forming a bridge over a large cavity, which could be likened to natural sounds such as flowing water in a stream. The sound of water falling onto an open cavity was believed to resemble water entering a sewer, and this was considered to be a negative feature, while a light temporal variation in the sound of the water was considered positive. It appeared that water sounds with a

* Corresponding author.
E-mail address: wyang@dankook.ac.kr (W. Yang).

https://doi.org/10.1016/j.apacoust.2018.01.028
Received 13 June 2017; Received in revised form 29 January 2018; Accepted 31 January 2018

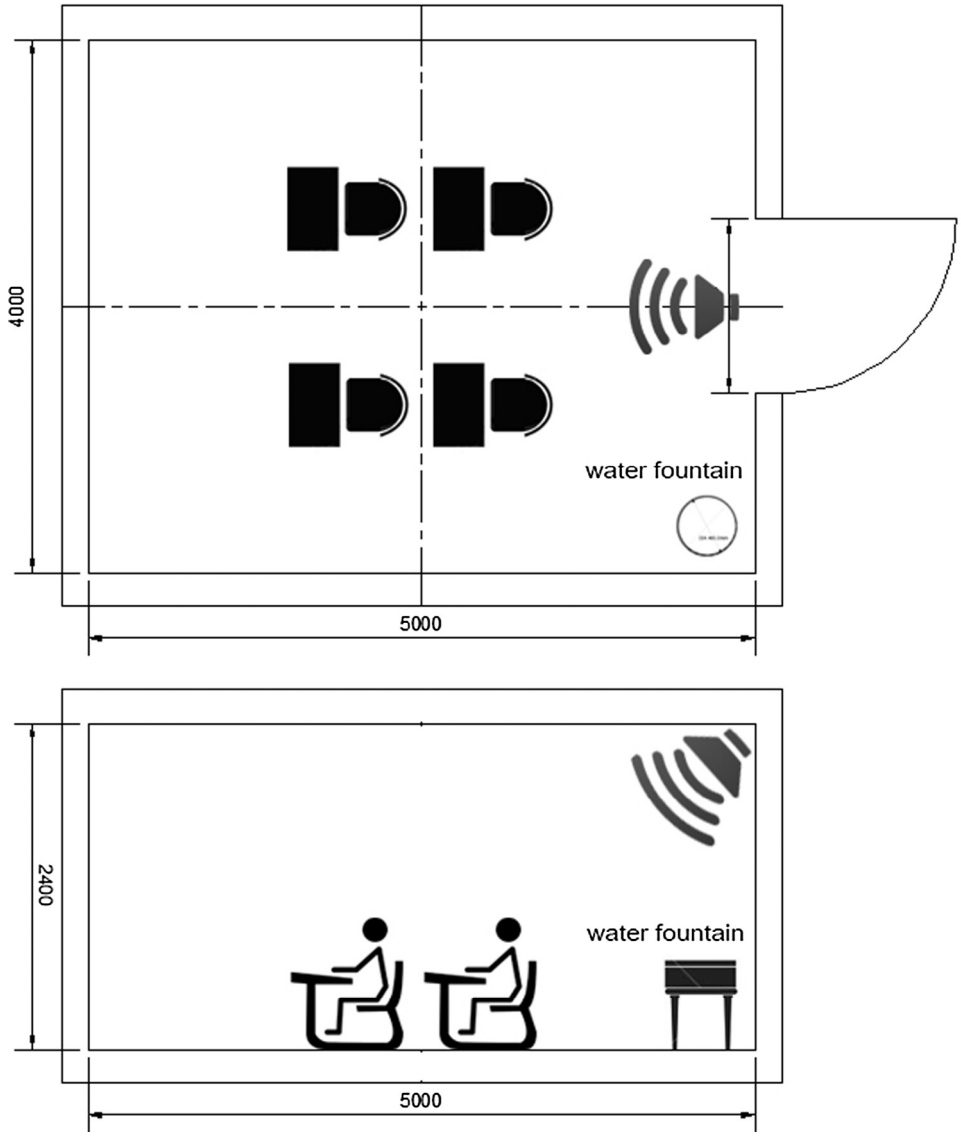

Fig. 1. Indoor environmental chamber layout.

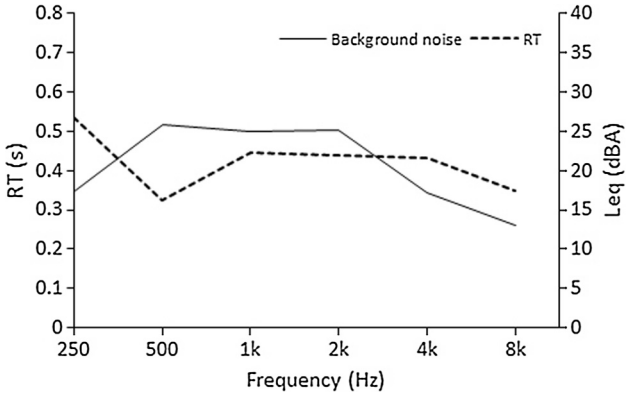

Fig. 2. Reverberation time and background noise level of indoor environmental chamber.

higher frequency variable were most highly rated in terms of tranquility. Jeon et al. [14] also focused on the spectral envelopes of water sounds. They concluded that sharpness was a dominant factor for urban soundscape perception and the preference of the urban soundscape could be described by adjectives such as “freshness (high sharpness)” and “calmness (low sharpness)”. Galbrun and Ali [15] examined the design of water features used in gardens and parks where road traffic noise is audible, with the aim of improving the soundscape of such spaces. Their auditory experiments indicated that the sounds of natural streams and fountains made of upward jets tend to be more suitable for improving peacefulness and relaxation in the presence of road traffic noise, whilst waterfall sounds are not satisfactory. The results suggested that masking based on spectral analysis alone should not be the driving criterion for designing water features; for example, while waterfalls presented better spectral properties for masking, they were not preferred due to their unsatisfactory sound. Their analysis on groups of sounds showed that low sharpness and large temporal variations were preferred on average for enhancing peacefulness and relaxation. Although the results by Galbrun and Ali [15] were inconsistent with those by Watts et al. [13] in terms of both temporal variation and spectral envelope of water sounds, the presence of water sounds enhanced tranquility, peacefulness and relaxation for masking traffic noise. Due to the complexity of physical and perceptual properties, it was revealed that no individual psychoacoustical character could be considered a key factor to measure the effects of water sounds.

Rådstern-Ekman et al. [16] evaluated the pleasantness of water sounds by selecting three water sounds – sea, stream, waterfall, with different degrees of pleasantness based on the results of their pilot