The influence of non-stationary vibrations on the quality of non-stationary product sounds

M. Ercan Altinsoy, Ute Jekosch

Institute of Communication Acoustics, Ruhr-University Bochum
email: ercan.altinsoy@rub.de, ute.jekosch@rub.de

Abstract

Mechanical vibrations of different products generate usually noise and additionally tactile information. In most cases, these auditory and tactile information are non-stationary signals. In the present study, a pilot psychophysical experiment was conducted to investigate the influence of non-stationary vibrations on the quality of non-stationary product sounds. In this experiment, non-stationary drill noise and vibrations were presented to the subjects via headphones and through a force-feedback mouse simultaneously. The influence of non-stationary vibrations on the quality of non-stationary product sounds will be discussed on the basis of the results of the psychophysical experiment.

Introduction

People are exposed to sound and vibration (also force-feedback) simultaneously, when operating a machine (household appliances, hand-power tools, etc.), travelling in the car, or in the airplane. Product vibrations may heavily influence the judgements on product-sound quality. From the view of a sound designer, tactile information can be used and designed to improve sound quality of products.
Most investigations which deal with the effect of vibration on judgements of noise, have focused on the annoyance or the discomfort caused by the noise. Paulsen and Kastka reported that the assessment of the annoyance caused by the noise could be increased by vibration, depending on the magnitudes of noise and vibration [1]. Hashimoto and Hatano investigated the effect of simultaneous exposure of noise and seat/floor/steering wheel vibrations with regard to unpleasantness of the car interior noise and found that vibrations strengthen unpleasantness, while visual information reduces unpleasantness [2]. Harris and Shoenberger showed that when vibration and noise are presented together, the impairment of cognitive performance is less than the one found under the noise alone condition (in this study noise and vibrations were called as stressors) [3].

Only very few investigations have focused on other aspects of product sound quality. Quehl et al. developed a semantic differential for aircraft interior sound and vibration. They have presented combined noise and vibration pairs in their experiments [4]. Västfjäll, Larsson, and Kleiner investigated also cross-modal interaction in interior aircraft sound quality evaluation. Their results showed that there is a strong cross-modal interaction between aural and tactile senses on the sound quality evaluation [5]. Daub and Altinsoy reported that the whole-body vibrations which are generated by musical excitations (stimulations) have pleasant and informative sensations on listeners [6]. Some investigations related to the influence of the visual information on the product sound quality were reported by Fastl [7] and Kohlrausch [8].

In the present study, a pilot psychophysical experiment was conducted to investigate the influence of non-stationary vibrations on the quality of non-stationary product sounds. Firstly a semantic differential was developed for the drilling machine. The sound and the vibration of two different drilling machines were evaluated using this semantic differential.

Experiment

Stimulus

The pilot experiment was related to drilling machines. It consists of three sessions: In the first session, only sounds of drilling machines were presented. In the second session only vibrations were presented, and in the third session sound and vibration of drilling machines were presented together. To evaluate the influence of temporal factors on the perception of sound quality, three different operational conditions of the drilling machine were selected, namely 1) fade in (acceleration), 2) drilling, 3) fade out (deceleration) (shown in Figure 1).

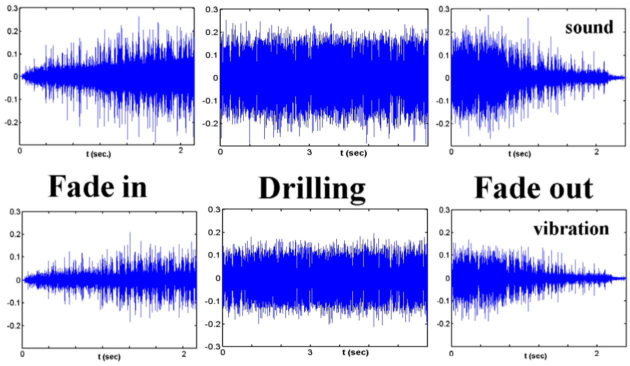

Figure 1. Sound and vibration recordings in three different operational conditions of drilling machine: Fade in, drilling, fade out

Set-up

The Saitek tactile feedback mouse was used to present the vibrations to the subjects. This mouse contains a motor that relates the vibration or the force-feedback sense to the hand guiding it. The subjects were instructed to hold the mouse in their hand and lift it from the table to avoid unwanted structural vibrations which can be generated from the contact between the mouse and the table and also to minimize the noise generated by the mouse.
The auditory stimulus was presented from a PC through Sennheiser HDA 200 closed-face dynamic headphones which have a very high sound isolation level and therefore mask the background noise of the mouse when it generates the signal. The experiments were conducted in a sound-attenuated room.

Subjects

The same ten subjects, six men and four women, aged between 24 and 46 years, participated in the experiment. All subjects had normal hearing and were right handed, with no known hand disorders. They used their right hand for the experiment.

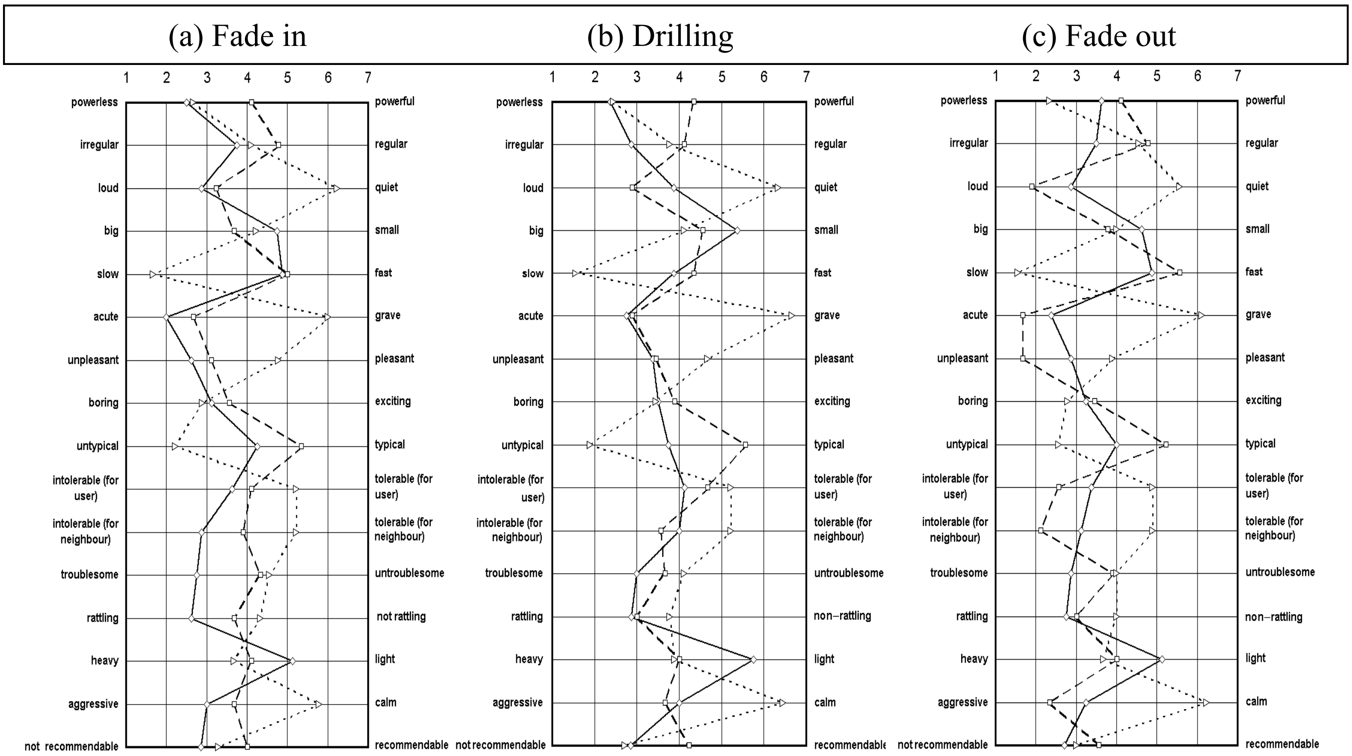

Figure 2. Semantic profiles of three different operational conditions of a drilling machine for three different stimulations; only sound (— —), only vibration (········), sound and vibration together (———). ((a) fade in, (b) drilling, (c) fade out).

Procedure

A Semantic Differential was developed for the drilling machine. This Semantic Differential consists of 16 adjective-pairs: powerless – powerful, irregular – regular, loud – quiet, big – small, slow – fast, acute – grave, unpleasant – pleasant, boring – exciting, untypical – typical, intolerable – tolerable (for user), intolerable – tolerable (for neighbour), troublesome – untroublesome, rattling – non-rattling, heavy – light, aggressive – calm, not recommendable – recommendable. The subjects indicated the intensity of their association on a seven-point scale.

Results

The judgements by 10 subjects were averaged and mean scores are shown in Figure 2. Looking at the data plots, it can be deduced that the attributes chosen are appropriate to capture the sensory profiles of auditory, tactile, and auditory-tactile stimuli of a drilling machine in an analytic way, both for non-stationary and stationary signals.

Discussion of Results

What the cross-modal interaction is concerned, there is no simple overall relation (i.e., dominance of one modality independent of the attributes), but one that is dependent on the attribute the judgement is based on. As an example, for the fade-in condition, there are cases where the tactile information obviously does not play any role (e.g. acute – grave), where it takes the main role (e.g., heavy – light), and where two individual modalities interact and lead to a combined perceptual event (loud – quiet). Interestingly enough, interaction is dependent on the operational condition of the drilling machine: With regard to the attribute ‘power’, vibration is the dominant modality in the fade-in and fade-out conditions, whereas the two individual modalities interact in the drilling condition. Comparable relations can be seen for the attribute ‘pleasantness’.

Acknowledgement

Part of this study was supported by the PROCOPE project. We would like to thank the DAAD and our colleagues at CNRS/LMA Marseille for their suggestions and support.

References

[1] Paulsen, R., Kastka, J., “Effects of combined noise and vibration on annoyance” Journal of Sound and Vibration, 181(2), 295-314,1995

[2] Hashimoto, T., Hatano, S., “Effect of factors other than sound to the perception of sound quality”, Proceedings of the 17th International Congress on Acoustics. Rome, Italy, 2001

[3] Harris, C.S., Schoenberger, R.W., “Combined effects of broadband noise and complex waveform vibration on cognitive performance” Aviation Space Environmental Medicine, 51, 1-5, 1980

[4] Quehl, J., Schick, A., Mellert, V., Schulte-Fortkamp, B., Remmers, H., “Dimensions of combined acoustic and vibration perception in aircrafts derived by factor analyis of semantic differential data”, in Proceedings of Internoise 2000, 465-469, France, 2000

[5] Västfjäll, D., Larsson, P., and Kleiner, M., “Cross-modal interaction between aural, tactile, and visual senses: Sound quality evaluation using a virtual aircraft”, (Submitted for publication) Journal of Sound and Vibration, 2004

[6] Daub, M., Altinsoy, M.E., “Audiotactile simultaneity perception of musical-produced whole-body vibrations” Proceedings of the Joint congress CFA/DAGA '04, Strasbourg, France, 2004

[7] Fastl, H., “Audio-visual interactions in loudness evaluation” accepted for the 18th International Congress on Acoustics, Kyoto, Japan, 2004

[8] Kohlrausch, A., van de Par, S., “Auditory-visual interaction: From fundamental research in cognitive psychology to (possible) applications”, in: Human Vision and Electronic Imaging IV, Proc. Soc. Photo-Optical Instrumentation Engrs. 3644 , 34-44, 1999