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Hugo Fastl Eberhard Zwicker

Psychoacoustics

Facts and Models

With 313 Figures and
53 Psychoacoustics Demonstrations on



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Preface to the Third Edition

As with the second edition of *Psychoacoustics – Facts and Models*, the style of the book in the third edition was also kept as a tribute to my mentor Eberhard Zwicker.

Since the book deals with psychoacoustics it was felt that it should be possible not only to read about psychoacoustic data, but also to hear some of the related phenomena. Therefore, a number of acoustic demonstrations have been prepared that are now available on an enclosed CD. The CD can be used as a traditional Audio-CD and the demos are also available as wav-files.

New sections on cognitive effects as well as localization with hearing instruments have been added. Moreover, in particular sections on noise measurements, noise immissions, loudness summation and recruitment, as well as musical acoustics were significantly expanded – the latter of course also with acoustic demonstrations. In addition, the list of references was updated in most sections.

The encouragement and fruitful cooperation of Springer Verlag, in particular of Dr. Thorsten Schneider and his team is gratefully acknowledged. Special thanks to Dr.-Ing. Markus Fruhmann and Dipl.-Ing. Daniel Menzel for their support in the preparation of the CD with acoustic demonstrations. Dipl.-Ing. Florian Völk is also acknowledged for substantial support in finalizing the CD, and for editorial help.

München
August 2006

Hugo Fastl

Preface to the Second Edition

Shortly after the appearance of the first edition of this book, the scientific community was shocked by the unexpected and untimely death of the great psychoacoustician Professor Eberhard Zwicker. The present second edition of *Psychoacoustics – Facts and Models* is meant as a tribute to my mentor Eberhard Zwicker, who was both an outstanding scientist and a dedicated teacher.

Therefore, the basic concept of the book has remained untouched. However, new results and references have been added in most chapters, in particular in Chap. 5 on pitch and pitch strength, Chap. 10 on fluctuation strength, Chap. 11 on roughness, and in Chap. 16 concerning examples of practical applications. In addition, occasional typographical errors have been corrected and some older material re-arranged. In essence, however, care was taken to keep the style of the original work.

The encouragement as well as the helpful and patient cooperation of Springer Verlag, especially of Dr. Helmut Lotsch, is gratefully acknowledged. My thanks go to the many students and co-workers who assisted in the preparation of the second edition, in particular Dipl.-Ing. Wolfgang Schmid and Dipl.-Ing. Thomas Filippou.

Munich
January 1999

H. Fastl

Preface to the First Edition

Acoustical communication is one of the fundamental prerequisites for the existence of human society. In this respect the characteristics of our receiver for acoustical signals, i.e. of the human hearing system, play a dominant role. The ability of our hearing system to receive information is determined not only by the qualitative relation between sound and impression, but also by the quantitative relation between acoustical stimuli and hearing sensations. With the advent of new digital audio techniques, the science of the hearing system as a receiver of acoustical information, i.e. the science of psychoacoustics, has gained additional importance. The features of the human hearing system will have to be taken into account in planning and realizing future acoustical communication systems in economically feasible projects: Each technical improvement in this area will be judged by listening and relating the result of listening to the cost.

In the years from 1952 to 1967, the research group on hearing phenomena at the Institute of Telecommunications in Stuttgart made important contributions to the quantitative correlation of acoustical stimuli and hearing sensations, i.e. to psychoacoustics. Since 1967, research groups at the Institute of Electroacoustics in Munich have continued to make progress in this field. The correlation between acoustical stimuli and hearing sensations is investigated both by acquiring sets of experimental data and by models which simulate the measured facts in an understandable way. This book summarizes the results of the above-mentioned research groups in two ways. First, the content of many papers originally written in German is made available in English. Second, the known psychoacoustical facts and the data produced from models are united to give an integrated picture and a deeper understanding. The references are confined to papers published by the two research groups mentioned, although there are naturally many more relevant papers in the literature.

The book is aimed primarily at research scientists, development engineers, and research students in the fields of psychoacoustics, audiology, auditory physiology, biophysics, audio engineering, musical acoustics, noise control, acoustical engineering, ENT medicine, communication and speech science. It may also be useful for advanced undergraduates in these disciplines. A special feature of the book is that it combines psychoacoustical facts, descriptive

models, and applications presented in the form of examples with hints for the solution of readers' problems.

The first three chapters give an introduction to the stimuli and procedures used in the experiments, to the basic facts of hearing, and to information processing in the auditory system. The important role played by the active processing within the inner ear is stressed in order to understand frequency selectivity and nonlinear behaviour of our hearing system. The next four chapters deal with frequency resolution and temporal resolution expressed in masking, pitch, critical bands and excitation, as well as just-noticeable changes in the sound parameters. The different kinds of pitch are described in Chap. 5, and the following six chapters deal with the basic sensations of loudness, sharpness, fluctuation strength, roughness, subjective duration, and rhythm. The next two chapters concern the ear's own nonlinear distortion and binaural hearing, with emphasis given to the topics that have been covered by the two research groups. The last chapter provides examples of applications, which will be of special interest to those engaged in finding practical solutions.

For didactical reasons, the text is not interrupted by the inclusion of references. However, at the end of the volume, the relevant literature published by the Stuttgart and Munich groups is cited, as is the literature dealing with the various applications given in the final chapter. The equations appearing in the book are given as "magnitude equations", containing not only symbols but also the units in which the variables are to be expressed. This should help to avoid mistakes since one can check the units of the calculated quantity.

Some of the figures contain more information than is needed for the immediate discussion. This is simply a device to save space and the additional information is invariably discussed at a later point in the text.

We would like to acknowledge the helpful and patient cooperation of Springer-Verlag. We thank the many individuals who contributed to the realization of this book, notably, Mrs. Angelika Kabierske for drawing the figures, Mrs. Barbi Ertel for typing the text, Dr. Frances Harris, Dr.-Ing. Tilmann Zwicker, and Dipl.-Ing. Gerhard Krump for reading drafts, and Dr. Bruce Henning for many very fruitful discussions and suggestions.

Munich,
June 1990

E. Zwicker
H. Fastl

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