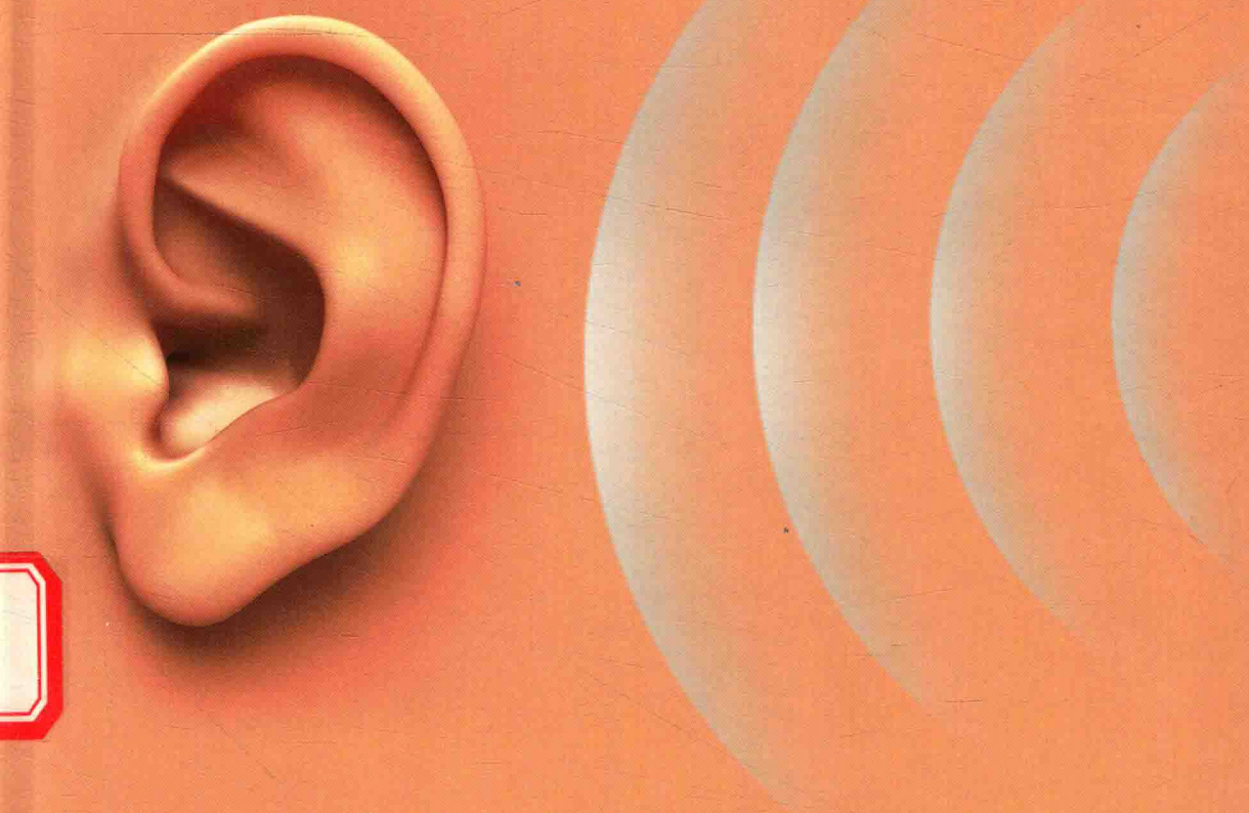
Wiley Series in Acoustics, Noise and Vibration

THE EFFECTS OF SOUND ON PEOPLE

JAMES P. COWAN



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Formulas for Dynamics, Acoustics and Vibration	Blevins	November 2015
Engineering Vibroacoustic Analysis: Methods and Applications	Hambric et al	April 2016
The Effects of Sound on People	Cowan	May 2016

To Al, Lorraine, Lynn, Josh, Beth, and Noah.

About the Author

James P. Cowan is a board-certified noise control engineer with more than 30 years' experience in noise control, architectural acoustics, and environmental noise issues. He has acted as a consultant to public agencies, architects, engineers, industrial personnel, and attorneys in all areas of noise control; hearing damage and protection criteria; and acoustic design of all types of spaces. Mr. Cowan has lectured on acoustical topics to thousands of professionals, delivering live seminars and webinars, and teaching courses for universities, professional societies, and private organizations across the US for more than 25 years. In addition to several book chapters and many published articles, Mr. Cowan is the author of *Architectural Acoustics Design Guide*, published by McGraw-Hill in 2000; *Architectural Acoustics*, an interactive educational CD set published by McGraw-Hill in 1999; and *Handbook of Environmental Acoustics*, a reference book in community noise issues published by Van Nostrand Reinhold (subsequently Wiley) in 1994. He is currently Principal Acoustical Engineer at AECOM in Manchester, NH, USA and Instructor in Acoustics at the Boston Architectural College in Boston, MA, USA.

Series Preface

This book series will embrace a wide spectrum of acoustics, noise and vibration topics from theoretical foundations to real world applications. Individual volumes included will range from specialist works of science to advanced undergraduate and graduate student texts. Books in the series will review the scientific principles of acoustics, describe special research studies and discuss solutions for noise and vibration problems in communities, industry and transportation.

The first books in the series include those on biomedical ultrasound, effects of sound on people, engineering acoustics, noise and vibration control, environmental noise management, sound intensity and wind farm noise – books on a wide variety of related topics.

The books I have edited for Wiley, *Encyclopedia of Acoustics* (1997), *Handbook of Acoustics* (1998) and *Handbook of Noise and Vibration Control* (2007), included over 400 chapters written by different authors. Each author had to restrict the chapter length on their special topics to no more than about 10 pages. The books in the current series will allow authors to provide much more in-depth coverage of their topic.

The series will be of interest to senior undergraduate and graduate students, consultants, and researchers in acoustics, noise and vibration and, in particular, those involved in engineering and scientific fields, including aerospace, automotive, biomedical, civil/structural, electrical, environmental, industrial, materials, naval architecture, and mechanical systems. In addition, the books will be of interest to practitioners and researchers in fields such as audiology, architecture, the environment, physics, signal processing, and speech.

Malcolm J. Crocker
Series editor

Preface

Sound is and always has been a source of pleasure and pain in our lives. Sound perception was key to our survival until recent times when its importance was diminished with the advent of secure shelter, but it still affects each of us profoundly. Only recently through credible scientific studies have we been able to understand why sound affects us in so many different ways. Parallel to this scientific exploration of the hearing mechanism has been the development of the field of acoustics, which has provided methods for describing sound behavior and rating its associated intensities. Descriptors in any technical field can be confusing without proper training, and the field of acoustics provides ample material to feed that confusion.

Regulations have been introduced since the 1970s to address the potential negative health effects associated with noise exposure, but the extent of those effects and a clear link between noise and anything other than hearing loss have not been adequately defined. The explosion of unfiltered information available to the public over the past decade through the internet has led to even more confusion and we are at a point at which it is difficult, if not impossible, for a person without technical knowledge in this field to separate credible from speculative information. It is with this in mind that this book has been written.

Karl Kryter wrote three seminal books on the negative effects of sound on people, published between 1970 and 1994 – *The Effects of Noise on Man* (1970), *Physiological, Psychological, and Social Effects of Noise* (1984), and *The Handbook of Hearing and the Effects of Noise* (1994) – each one building on the next. These volumes were comprehensive and technical, and many changes have occurred since they were published, especially in terms of research results and the types of noise sources of concern to the public. This book is not meant to replace any of the valuable contributions Dr. Kryter has made to the field of psychoacoustics and, besides these works, there is no single book available that summarizes research efforts related to the effects of sound on people.

This book is for the non-technical student interested in understanding the state of current research in this field. More than 1,000 references were reviewed and close to 500 were included as those being the most credible, unique, and relevant to the latest research results. The descriptors commonly used in these publications are explained, along with common misinterpretations and misuses of the descriptors from experience and review of speculative publications.

Chapter 1 starts with an assumption of no background in acoustics by explaining the most basic acoustic parameters involved with sound generation and propagation both

indoors and outdoors. Chapter 2 builds on this foundation by explaining the most common descriptors used in these studies. A key point with these descriptors is consistency, as any conclusion can be drawn from a study by choosing descriptors that support the desired conclusions. Without consistency in descriptors and their proper use, there is no credibility in reported results. Chapter 3 gives an overview of the hearing process, explaining generally how it works and what can happen when its delicate mechanism is not operating in perfect order. Alternate means of hearing (beside the normal channel) are described, along with an introduction to hypersensitivities that have not received much serious attention.

Chapter 4 summarizes the state of research in negative physiological effects associated with sound, from well-established results in noise-induced hearing loss to lesser-known ongoing research addressing the links between sound exposure and cardiovascular diseases, along with low-frequency and infrasound concerns. Chapter 5 summarizes the state of research in negative psychological effects associated with sound, covering the most-studied topics of annoyance, stress, sleep disturbance, learning disabilities, and emotional effects.

Chapter 6 continues with descriptions of the characteristics of current sound sources associated with negative sound effects to explain the aspects of these sources that contribute to their negative effects. Included in this discussion are transportation sources (roadway, aircraft, and rail), industrial sources (including traditional power plants and wind farms), recreational sources (such as firearms, public performances, toys, personal listening devices, and tools), hums (sounds only heard by some with no obvious origin), and the fallacies and realities of acoustic weapons.

Topics not often seen in these types of books are those related to the positive effects of sound on people. It is important to consider the positive as well as the negative effects when addressing the effects of sound to determine the most practical and effective alternatives to solving sound issues. In this regard, Chapter 7 summarizes the state of research in music psychology, sound therapies, soundscapes, and the ways in which sound is used to influence human behavior in common public environments. The book then finishes with the topics of sound control and regulation in Chapter 8, explaining noise control design and regulatory methods with common limits to inform the reader of the practical options available in dealing with negative sound issues. A glossary completes the book as a handy reference for explaining the many technical terms used in the book and public documents associated with this topic.

As mentioned above, more than 1,000 references were consulted for this book, and this would not have been possible without the invaluable services provided to me through the Boston Architectural College, where I've been teaching acoustics courses online for the past 16 years. My sincere appreciation goes out to the library staff under the leadership of Susan Lewis and Whitney Vitale, namely, Robert Adams, Erica Jensen, Toshika Suzuki, Sheri Rosenzweig, Rebecca Baker, Geoffrey Staysniak, Celia Contelmo, Christina Leshock, and Kris Liberman.

Jim Cowan
August 2015

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