Chapter 1

Introduction

Hearing disorders represent a socio–economic problem, since approximately 10 – 15 % of the total population in western countries experiences a significant hearing loss. The performance of individuals with sensorineural hearing loss, i.e., hearing loss of cochlear or retrocochlear origin, is often different from that of normal–hearing subjects in many auditory perceptual tasks, for instance speech perception or loudness perception, even when compared at the same sensation level (i.e., the sound pressure level above the individual absolute threshold). This is due to alterations in auditory signal processing following cochlear damage. Therefore, unlike damage to the middle ear, cochlear damage is not only associated with changes in the sensitivity of the auditory system to weak sounds ("attenuation component"), but also with changes in the perception of supra–threshold stimuli ("distortion component").

Most sensorineural hearing–impaired subjects show a phenomenon commonly referred to as *loudness recruitment*. When a sound is increased in level above (raised) absolute threshold, the rate of growth of perceived loudness with increasing level is greater in hearing–impaired subjects than in normal–hearing subjects. However, perceived loudness in hearing–impaired subjects approaches "normal" values at high sound pressure levels (i.e., 90 – 100 dB SPL). Thus, at low and medium levels, loudness perception is altered, i.e., it is pathological, while it appears to be normal at high levels.

Recent research has provided increasing evidence that restoring loudness perception might improve the performance of hearing–impaired individuals in other psychoacoustic tasks, such as speech perception. Several approaches have been proposed to restore loudness perception using different types of multichannel dynamic compression hearing aids. However, to optimally restore loudness perception it is necessary to determine the correct subjective loudness for different stimuli, such as narrowband or broadband signals. Therefore, in this study loudness perception for different stimuli is investigated in sensorineural hearing–impaired subjects. On the basis of these experimental data, a loudness model accounting for hearing impairment is developed from which subjective loudness can be derived for different stimulus conditions.

In chapter 2 the physiological correlates of hearing impairment of cochlear origin are discussed in detail. Specifically, a decomposition of cochlear hearing loss into two components, a loss of sensitivity and a loss of compression, is discussed. Chapter 3 describes different techniques to measure functions relating subjective loudness to sound pressure level, i.e., "loudness functions" or "loudness growth functions". These functions play a major role for modeling loudness perception in sensorineural hearing–impaired subjects appropriately. Therefore, the results from experiments with normal–hearing subjects employing three different loudness scales are discussed, i.e., absolute magnitude estimation, restricted magnitude estimation and categorical scaling with many categories. In chapter 4, the application of the categorical scaling technique is investigated using hearing–impaired listeners. Specifically, the correlation between audiometric threshold and amount of recruitment is analysed. The influence of signal bandwidth on perceived subjective loudness will be investigated in chapter 5. Experiments employing signals of differing bandwidth were performed with normal–hearing and hearing–impaired subjects using a categorical scaling technique. Chapter 6 describes different approaches to the modeling of loudness perception, one purely "psychological" (which does not account for physiological findings but relates perceived loudness to stimulus level using a power law) and one purely "physiological" (which does not relate stimulus level to subjective loudness). It is shown that neither approach provides a reliable model for describing loudness perception in hearing–impaired subjects. In chapter 7 a loudness model originally proposed by Zwicker is extended to describe the data measured in chapter 5. This model combines the power law relationship between stimulus level and subjective loudness seen in the psychological models, with basic properties of auditory signal processing, seen in physiological data. We discuss two modifications of Zwicker's model to take into account hearing impairment. These modifications differ in the way they model loudness recruitment.