Psychoacoustics Without Psychology?

R. Guski, J. Blauert
Ruhr-University Bochum, Germany Rainer.Guski@rub.de *Jens.Blauert@rub.de*

Introduction

The term *psychoacoustics* is generally defined as the study of listeners' responses to sounds. More specifically, psychoacoustics looks for statistical and causal relationships between certain physical properties of sounds and certain properties of human responses. It is assumed that physical and psychological properties are corresponding. This can be questioned (e.g., [7]), but we shall stick for the moment to the traditional definition. In a typical psychoacoustic experiment, listeners are subjected to a series of brief sounds that vary in a certain physical dimension, and listeners are requested to scale the psychological attribute of that physical dimension. In the early years of psychoacoustic experimentation, the experimenters looked for so-called "simple stimuli" and "simple responses", e.g., brief sine waves of varying levels on the acoustic side, and yes/no or numeric responses on the psycho-side. It soon turned out that there was a considerably variability of psychometric functions across laboratories, procedures, and listeners, sometimes even with the same listeners at different points in time. This variability was partly seen as a nuisance that could be overcome by proper training of listeners [20], partly as an interesting aspect of human behaviour, stimulating further methodological research [3]. Today, the first group of scientists replaced listeners by algorithms and construct machines playing "psychoacoustics" without much "response error", while the second group engages in analysing the influence of context on human multidimensional judgements.

Context Effects in Psychoacoustics

Generally speaking, there is no such thing like perception or measurement without context − especially in real life situations. Even if you measure the length of a line on a sheet of steel, you use a ruler and obey certain rules: These rules specify the measurement scale (e.g., a linear scale starting at zero with steps of centimeters or inches), and the environmental circumstances of measurement (e.g., temperature and evenness of the surface). The rules specify the measurement context, and they help greatly to get reproducible results. However, it is intuitively clear that the context, particularly, measurement scale and measurement circumstances, has a huge influence on the measurement results, leading to low generaliseability of measurement results across different circumstances.

From a psychological point of view, context has at least three dimensions, namely, space, time, and semantics [1]. We can easily add the response situation as a fourth dimension. A few psychoacoustic examples may suffice to illustrate the importance of each dimension:

1. Spatial context: (a) Binaural sound presentation leads to higher loudness judgements than monaural presentation [19]; (b) Detection of weak stimuli increases when sounds are presented from a narrow range of directions [14]; (c) When two sounds are presented from similar locations, they tend to be attributed to the same (or a similar) source [2]; (d) If a sound occurs in the vicinity of a visual object that is interpretable as a plausible sound source, the auditory localisation tends to be "captured" by the visual object [8].

2. Time context: (a) If two sounds arrive at the listener at the same time, they tend to mask each other [18]; (b) If two sounds arrive at the listener in close succession, the sound is attributed to the same (or a similar) source [2]; (c) If a visual event precedes the sound, the perceivers tend to attribute the source of sound to the visual event [4].

3. Semantic context: (a) Sounds that are meaningful to listeners are detected faster and at softer levels than neutral sounds [16]; (b) Sounds that are meaningful to listeners attract more attention and have a greater detrimental effect on visual tasks than neutral sounds have [6]; (c) Visual information that fits the sound semantically either increases or decreases the judged loudness of the sound − depending on the actual evaluation of the sound source [11, 17].

4. Response situation: (a) Both range and frequencies of sounds contribute to the judgement on sounds [9]; (b) Different scaling procedures (e.g. absolute magnitude production vs. category scaling) lead to different psychoacoustic functions [3]; (c) The sequence of sounds used in the experiment has a large influence on the individual judgement of sound properties [5].

If algorithmic procedures calculate "psychoacoustic" properties of sounds, they use listening results obtained in a special context. The results are by no means "unbiased", but they represent psychoacoustic functions that can be easily reproduced in listening experiments using the same particular context. Yet, it is questionable whether these functions can be generalised across situations and whether they are actually valid estimates of the average behaviour of listeners outside laboratory environments.

Alternative Psychoacoustics?

Psychologists tend to say that absolute judgements are a very difficult task for humans to perform. Therefore, their preferred psychophysical procedures require relative judgements, stressing the cognitive basis of psychophysical judgements. This movement started with Helson's [5] idea of *adaptation levels* − changing over time, but still resting on the assumption of a sensory nature of psychophysical judgements, proceeded to so-called *frame-of-reference theories*, like the *Similarity-Classification (SC) Model* [12] which can be seen as perceptual−cognitive model of stimulus classification: A focal sound is classified within the implicit or explicit variable context. In Parducci's *Range-Frequency (RF) Model* [9, 10], judgements are seen as a compromise between two different cognitive tendencies of humans; namely, (1) the tendency to divide the range of mental stimulus representations into equal sections, and (2) the tendency to assign the same frequency (i.e. number) of stimuli to each category. In the course of the series presentations the judgement scale changes as a function both of the range and of the stimulus-frequency distribution. While the three methods mentioned so far focus on verbal behaviour (e.g., scaling), Sarris [13] suggests behavioural psychophysical methods that can be used even with children or animals, and may be useful in applied settings. For instance, Trehub et al. [15] trained children between 6 and 18 months of age to turn their heads in the direction of an active loudspeaker and observed localisation responses for octave-band sounds with different centre frequencies in each age group.

One of the greatest obstacles for applying conventional psychoacoustic results to real-life situations is their restriction to one single modality. Perception in the world outside laboratories is multimodal with at least two-sensory modalities. Given healthy listeners, they usually listen with their eyes open, they often look at the source of sounds, and even if they can not see the sound source, they use the visual context in order to decide whether the sounds fit the visual scene or not. This situation is somewhat different from the classic context effect mentioned above: Since human listeners spontaneously tend to search visually for the source of sound, we expect strong neuronal and behavioural connections between audition and vision. This makes applications of pure auditory psychophysical results to real-life problems much more difficult as compared to pure visual psychophysics. In any case, multivariate psychophysics including psychoacoustics seems more appropriate to deal with human perception.

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