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Methodological approaches to investigate the effects of meaning, expectations and context in listening experiments

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ABSTRACT

Cognitive factors in sound evaluation have received an increasing amount of attention over the past years, and specific effects of meaning, expectations, and context have been under empirical investigation. The present paper is intended to contribute to the theoretical definition of these concepts as well as to demonstrate their impact on the auditory assessments in selected empirical studies. To that effect, first the effects of source identifiability on loudness and annoyance judgements of environmental sounds are presented. Further, the concept of user expectations and its implications in applied situations is illustrated with examples from automotive research and development, pointing to the fundamental distinction between sound character and sound quality as proposed by [1]. Finally, the term context is defined within the theoretical framework of reference frames, and effects of the immediate stimulus context on ratings of auditory pleasantness are presented.

1 INTRODUCTION

The significance of non-sensory factors for human sound evaluation has been increasingly acknowledged, and numerous investigations have demonstrated the impact of psychological variables in listening experiments [2]. It is argued that the mere focus on the acoustic properties of a sound is not sufficient but cognitive and affective variables such as attitudes, user expectations, meaning, and preferences are relevant in the evaluation process. Likewise, the relativism of psychophysical judgements is common sense, and it is widely accepted that context variables have to be accounted for in listening experiments [3]. Accordingly, a large body of

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studies is available substantiating the significance of various types of contextual variables. In the discussion along these lines it is sometimes implied that auditory assessments have a tendency to be vague, and the fact is stressed that human responses are dependent on influences of the experimental situation as well as on a large array of intra- and interpersonal variables. By contrast, instrumental assessments of sounds are considered unbiased, thus they are occasionally labelled “objective” as opposed to the “subjective” data from auditory assessments.

Clearly, both auditory and instrumental assessments may yield objective results founded on respective measurement theories (see [4]). It goes without saying that both methodologies cannot be substituted for each other but should always be used as complementary approaches to the measurement of auditory attributes. In applied contexts such as the sound engineering of technical products, for instance, the goal is to develop tools for reliable as well as economic measurements of sound characters. This is due to the fact that efficient sound engineering rests on precise goal specification, which in turn requires establishing measurable criteria throughout the product development process. The starting point in this endeavour usually is the auditory assessment of relevant auditory phenomena with subsequent exploration of the perceptual space by means of psychological methods (e.g., Semantic Differential Technique). Multivariate statistical analyses (e.g., factor analysis, cluster analysis) may uncover higher-order perceptual dimensions which specify variables to be predicted in respective psychoacoustic models. Finally, algorithms for the instrumental assessment of the auditory attributes targeted may be developed for routine use in the engineering process.

The key for proper sound evaluation in the aforementioned sense, therefore, is careful administration of psychological methods in listening experiments comparable to the standards defined for instrumental measurements. As [5] has pointed out, “because a perceptual response is being sought, there is a tendency to believe that the methods employed can be more casual, but in fact the opposite is the case” (p. 6). In contrast to the field of physical measurements, however, only sparse publications are available which provide guidelines for the application of psychometric methods in the field. Standards are urgently needed to ensure that acoustic engineers derive maximum benefit from psychological methods and avoid pitfalls. It is true that psychological and sociological issues have been discussed more frequently in the past, yet there is still a high demand for precise specification of how to deal with these issues.

This paper is intended to take up three major psychological issues that have been recently addressed in academic and applied research projects by the present authors. First, the notion of meaning will be addressed which is assumed to reflect cognitive and affective appraisals of sounds succeeding their source identification (see Figure 1). Further, the cognitive concept of user expectations will be discussed in the light of product sound quality, and practical implications will be reported from automotive research and development. Finally, the issue of context is addressed, and effects of the immediate stimulus context on ratings of auditory pleasantness will be presented.

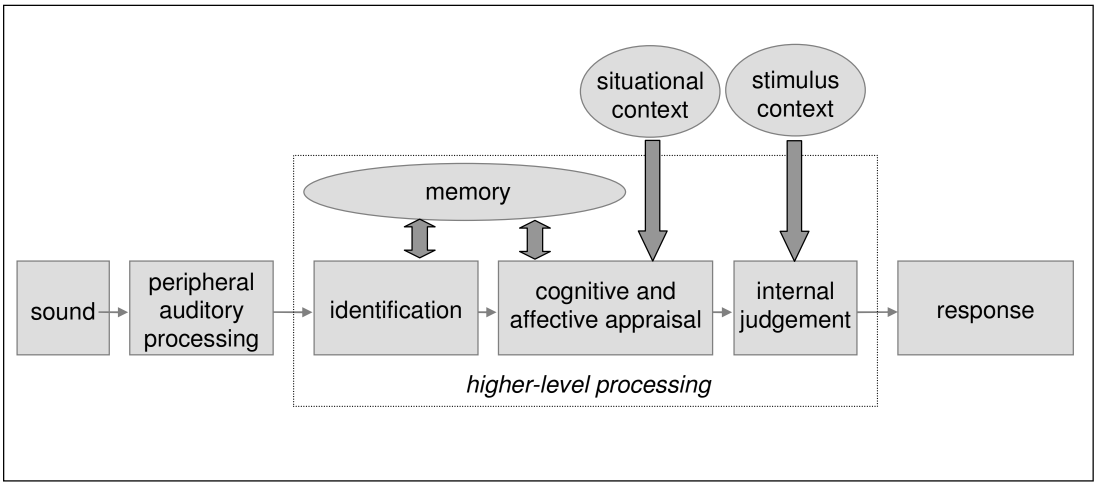

Figure 1: Auditory processing in listening experiments (working model).

2 EFFECTS OF MEANING

2.1 Theoretical Framework

Several authors have stressed the psychological perspective to sound evaluation by pointing to the concept of meaning [2][6][7]. It is argued that "every auditory perception, every auditory experience, every auditory event is not only based on sensory conditions: rather, a great deal of non-conscious knowledge is added, for example in the form of conveying meaning" [6, p. 2522]. In the realm of product sound quality it is assumed that the meaning of a sound is important in the customers´ decision to purchase a product. Likewise, the meaning that an individual attaches to an environmental noise is crucial for its acceptance and thus determines whether or not it is annoying. In his line of reasoning, [7] has pointed out that the subjective meaning of a sound may vary considerably among subjects. This implies to shift away from the stimulus-centred approach, and to move the individual in the centre of the examination.

Recently, a theoretical framework for the meaning of sounds was provided by [8] in her attempt to adopt the semiotic approach for human sound evaluation. Semiotics views each sound as a sign which is characterized through the semiotic triangle consisting of form, content and recipient. Form refers to the acoustic features of a sound which are perceived by the listener (interpreter) as an auditory event, while content is equivalent to the meaning attached to the auditory event according to the specific context situation. It is argued that "there is no natural relation between form and content of a sign, but it is the interpreter who associates a meaning to a form" (p. 681). Importantly, each sign constitutes a relationship between the sign carrier (signifier, i.e., the sound) and the object in the world (signified, e.g., technical device). Consequently, the meaning that is attached to a sound changes as the relationship between signifier and signified alters. If, however, the sound becomes unrecognizable for the subject, no relationship between sound and physical objects can be established thus no meaning evolves.

2.2 Empirical Investigations

The latter rationale was adopted in several studies on the effects of source identifiability on loudness and annoyance judgements [9][10][11]. The experiments used a signal processing scheme proposed by [9] which rendered the original signals so as to largely obscure their identifiability while preserving their loudness-time functions as well as spectral envelopes. This method first analyses the original signal by means of an FTT, applies some spectral broadening, and finally uses an inverse FTT for synthesis (for details see [9]).

In a study [11] which aimed at disentangling sensory and non-sensory factors in loudness and annoyance judgements the aforementioned method of signal-processing was applied to a set of 40 environmental sounds ranging from 30 to 80 dB SPL. Most of them were non-stationary sounds from every-day situations (e.g., water tap, door closing, scissors), or sounds from electrical devices recorded in their typical use (e.g., razor, hair dryer). The signals had been identified as highly recognizable in their original condition in a pilot study. Four independent groups of test subjects (N = 25 each) were asked to provide either annoyance or loudness judgements of the original or processed signals. In addition, the participants completed a semantic differential comprised of 12 concept-specific adjective pairs to grasp aspects of the denotative and connotative meaning of the sounds.

As a result, significant mean differences in the loudness judgements of original and processed signals were found only for 3 out of 40 stimuli. It was concluded that source identification was not crucial for the loudness impression. In the annoyance condition, a significant main effect was found indicating that the processed signals were judged more annoying on the average; post-hoc tests yielded significant mean differences for 7 out of 40 stimuli. Both psychoacoustic parameters and the meaning of the sounds were assumed to account for the discrepancies in the annoyance judgements. It was further shown that mean differences in both scaling tasks were well correlated with a number of semantic scales. It may thus be concluded that the Semantic Differential Technique may pick even small differences in meaning thus providing a powerful tool for auditory assessments in sound quality research.

3 EXPECTATIONS IN JUDGEMENTS OF SOUND QUALITY

3.1 Theoretical Framework

In their definition of sound quality, [12] stress the suitability aspect and require the sound to be adequate for the technical functioning of the product. Whether or not a sound is suitable for a given product is dependent also on user expectations which have to be accounted for so as to meet the requirements of human machine interaction. At this point it is worthwhile to make a distinction between sound quality and sound character [1]. The latter concept refers to the unbiased sensory properties of the sound implying that these are neutral descriptions to the largest extent. By contrast, sound quality includes also the cognitive and affective appraisal of the sound, and is dependent on a large variety of context factors. Accordingly, cognitive factors such as user expectations play an important role in the evaluation process but they should not manifest themselves in the assessment of sound characters. While judgements of sound quality thus are relative in nature, the auditory assessment of sound characters ideally is devoid of contextual conditions by analogy to instrumental assessments. For instance, the question whether or not the operating noise that is fed back to the user of a technical product is loud enough matters its sound quality, while the mere description of the loudness level is an aspect of its sound character. The following paragraph will further elaborate this issue in the light of the sound engineering of automobiles.

3.2 Sound Character vs. Sound Quality of Automotive Noises

Sound design has become an integral part of the branding strategy in the automotive industry [13]. Different design goals apply to the sound engineering depending on the functional and aesthetic requirements that have been specified for a particular type of exterior or interior noise.

The sound quality of driving noise in the interior of vehicles can be defined as the extent to which the sound character matches the overall vehicle character and supports brand values [14]. This principle is illustrated in Figure 2 which contains an example of the acoustic vehicle positioning of a car manufacturer. Driving noise which is composed of wind, rolling and engine noise is specified for cruise at constant speed on the one hand (y-axis), and for the sound feed back during accelerations on the other (x-axis). In the positioning of vehicles along these two dimensions different requirements apply depending on the vehicle type. As for luxury sedans both the sound level during cruise and the acoustical feedback during acceleration should be at low levels. By contrast, the sound characters of sports cars or roadsters require the feedback of larger amounts of engine sound to the driver to support the sporty character of the vehicle.

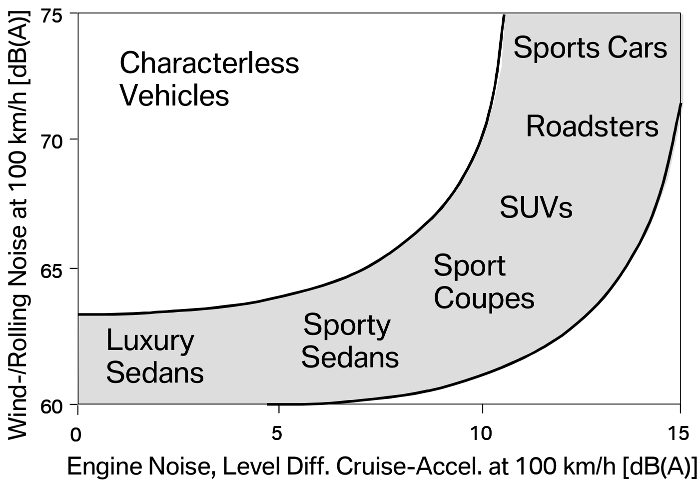

Figure 2: Acoustic vehicle positioning of a car manufacturer. Different sound characters as defined by the noise levels during cruise (y-axis) and acceleration (x-axis) are required depending on the vehicle type.

In an empirical study that was performed to inquire into perceived attributes of driving noise and correlating psychoacoustic parameters, auditory assessments of a total of 29 vehicles were performed by experts ($N = 28$) during cruise and acceleration [14]. The Semantic Differential Technique was used to obtain multidimensional descriptions of the sound characters of several vehicle types (e.g., sedans, sports cars, SUVs) stemming from different manufacturers. It was shown that profile differences among brands were small within a particular vehicle type as opposed to the profiles for contrasting vehicle types. As exemplified in Figure 3 the sound character of sports cars during acceleration was designed so as to emphasize the “sporty” vehicle character in terms of lesser convenience. By contrast, luxury sedans have in common to pronounce auditory pleasantness which is reflected, for instance, in quieter and smoother noises.

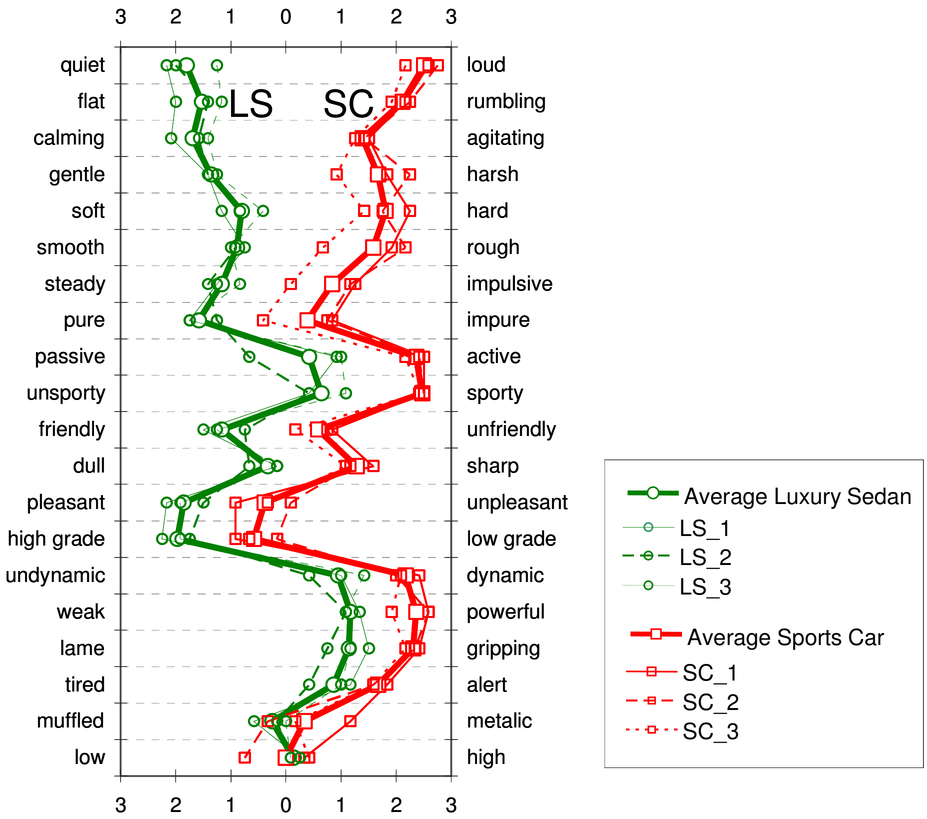

Figure 3. Semantic profiles of sound characters of luxury sedans (LS, circles), and sports cars (SC, rectangles) during acceleration.

4 CONTEXT IN SCALING TASKS

4.1 Theoretical Definitions

In this article the term context is used to denote the relativism of psychophysical judgements in listening experiments. The context dependency of psychophysical judgements is well accepted, and numerous publications have demonstrated substantial effects of a host of variables, including stimulus range, stimulus spacing, stimulus sequence, prior experience, and experimental setting [15]. Contextual effects have appeared in various response scales including both category scaling and magnitude estimation tasks. The context dependency of categorial judgements, however, has received special attention in empirical research into theories of reference frame. The current definition of reference frame refers to the fact that absolute judgements are not absolute in the literal sense but based on standards that are immediately in effect during the cognitive processing of auditory stimuli (see Figure 1).

Among the various types of contextual effects, the impact of the stimulus context has been of particular interest for prominent approaches such as Parducci's range-model [16]. The range-principle asserts that subjects map the endpoints of the contextual range, i.e., the stimulus series, onto the extreme categories of the scale. Further, it is assumed that categories are assigned to equal segments of the stimulus range. The experiment reported in the following shall exemplify the range-principle for pleasantness judgements of engine noises.

4.2 Impact of Stimulus Context on Categorical Judgements of Auditory Pleasantness

The experiment was performed to examine the extent to which the immediate stimulus context has an impact on the assessment of the auditory pleasantness of engine noises [15]. A set of four engine noises on idle was contained in three stimulus series which varied in their composition of sound types, hence in the range that was covered on the pleasantness continuum (large – medium – small). In condition "large" the stimulus series ($N = 52$) was comprised of diverse environmental sounds including instrumental music, vocal music, animal sounds, ringing of bells, operating noises from car engines, household appliances, and power tools. The medium range stimulus series ($N = 9$) was consisted of noises from household appliances in their typical use (electric coffee grinder, hair dryer, hand mixer, old-fashioned alarm clock, and vacuum cleaner). Only engine noises were used in the in the small range stimulus set ($N = 8$). Three independent samples of test subjects ($N = 26$ each) were assigned to rate the pleasantness of the sounds by means of a 7-point category-scale (see Figure 4). Prior to the scalings, subjects were presented with all sounds to provide for orientation of the stimulus series.

Figure 4 shows that mean pleasantness ratings of the engine noises were highly dependent on the immediate stimulus context in that the category range employed for the four engine noises increased as the range of the surrounding stimuli decreased. However, the judgements were not solely determined in relation to the endpoints of the contextual range as predicted by the range-principle. Rather, the results give evidence that a strong resistance against the experimentally induced context came into effect caused by the verbal anchoring of the scale and the method of absolute judgements. It is assumed that this result is largely due to the type of stimuli in that the sounds were familiar and thus meaningful to the subjects. The results suggest that the meaningfulness of the stimuli is an important moderator variable in the prediction of contextual effects.

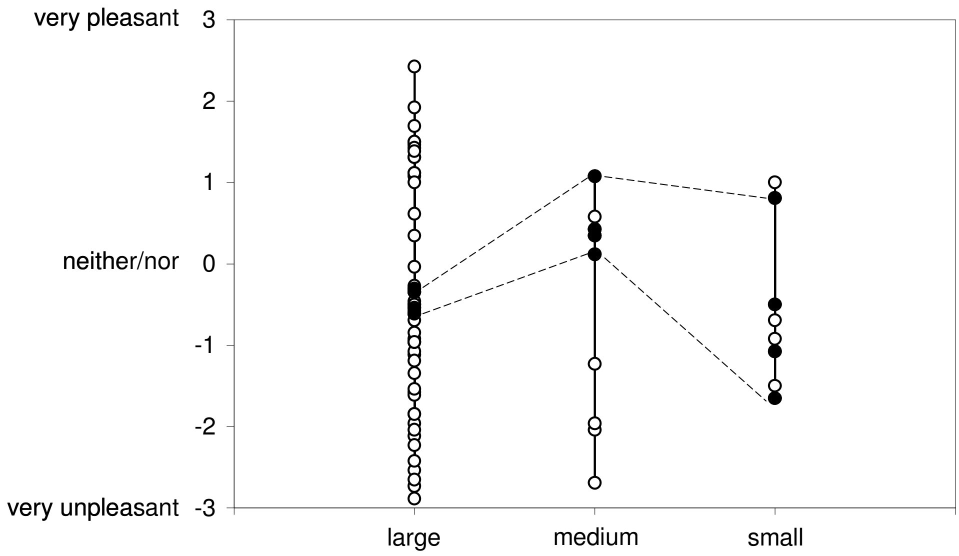

Figure 4. Mean pleasantness judgements of the four engine noises (filled circles), and contextual stimuli (open circles) in the three experimental conditions. Standard deviations: 0,33 to 2,04: median: 1,06 scale units)

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