On the use of psychoacoustical and psychophysical methods to predict consumer preference for interior car sounds

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Introduction

"Product sound quality" (PSQ) is today a standard concept in the development of many consumer products. PSQ is a determining factor for user acceptance and satisfaction. In response to this, the industry often applies "user-oriented" methods. These methods are however often time-consuming and costly, and for that reason may not be used to the extent that is needed. A major challenge to industry is improve the PSQ design process by the use of efficient prediction tools and development of novel methods that will decrease the cost associated with user-oriented methods.

PSQ studies often consist of three data outputs: 1) physical properties characterized by metrics (incl. psychoacoustic metrics), 2 subjectively measurable physical properties obtained by having trained listeners provide sensory ratings (humans as analysis systems), and 3) subjective preference obtained by asking relevant user groups/naïve listeners (humans as consumers).

The present article outlines a method (MultiDimensional Unfolding: MDU) developed to extract such information from physical properties, sensory-, and preference ratings [1].

MDU

PSQ research has tended to mainly rely on subjective ratings obtained with scales that have predefined adjectives attached to them. The use of such methods is a relevant approach if the perceptual/subjective dimensions are known a priori and are well-defined. The initial stages of many PSQ investigations however lack the theoretical rigor to guide the choice of adjectives/subjective dimensions. Using this approach important subjective aspects may not be captured. An additional problem is that the validity of subjective scales sometimes can be questioned [2]. An alternative approach that avoids the assumptions made by traditional subjective scales is MDU. It is based on four different steps, which are briefly described here (for a more detailed overview see [1]). The core concept of MDU is to, by the use of statistical procedures, connect the three types of data described earlier.

Semantic scale evaluation: Expert listeners rate sounds on an evaluated adjective scale. This data is analyzed with Principal Component Analysis(PCA) apart from the common variance analysis.

Multi-Dimensional Scaling (MDS): Expert listeners evaluate the difference between the sounds in a paired comparison design. The result of the analysis will be a Perceptual space where the sounds will be positioned in different locations.

Preference mapping: Naïve listeners (customers) rate their preference for the sounds in a paired comparison design, which after analysis will result in a ratio-scale using BTL [3].

Synthesis of the results: The results from step one and three are connected to the results from step two by the use of regression analysis. The results from step one will help interpreting the perceptual dimensions underlying the stimuli-set. The results from step three will show which of these dimensions are important for preference among the sounds.

Experiment

The benefit of the MDU method is demonstrated in a PSQ experiment, focusing on interior car sounds with tonal components from the transmission. To a have control over the sounds, (to be able to evaluate the method), synthesized sounds were used. The tonal component was altered in three ways; *level, length* and *amplitude-modulation frequency* of the tone.

Step 1: 20 expert listeners were asked to rate 18 sounds on 23 different adjectives [4, 5]. The PCA resulted in five reliable dimensions, named *quality, audibility, tonality, modulation* and *safety*, from the content of each component. These components explained 79% of the variance present. One example of the ratings of the sounds on these components can be seen in Figure 1.

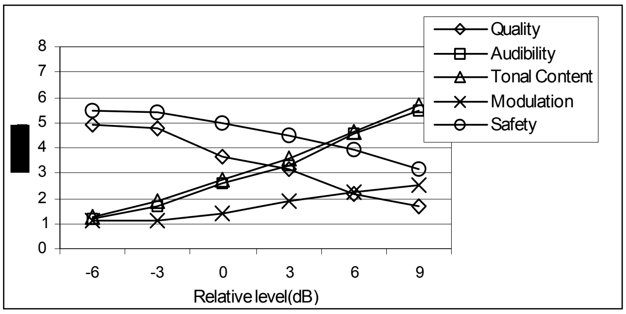

Figure 1*:* Relative level of the tone vs. ratings on the principal components.

Step 2: A subset of the stimuli used in step 1 was presented to 10 expert listeners. In the subset sounds that got similar ratings in step 1, was removed. The MDS analysis resulted in three dimensions, explaining 97 % of the variance present. By inspection from the physical aspects, the dimensions could be interpreted bye means of the physical properties of the sounds, since the sounds where synthesized. dim 1 sort the sounds by modulation frequency and dim 2 is mainly concerning the audibility for the tone in the sound

Step 3: A subset of the stimuli from step 1 was presented to 21 naïve listeners. The test was done in a half-matrix paired comparison design. The data was analyzed with Bradley-Terry Luce (BTL), which resulted in a ratio-scale with the sounds positioned in one dimension.

Step 4: All data from step 1-3 were connected with statistical methods that make the results from step 1 and 3 interpretable as vectors in the perceptual space from step 2. These vectors help the interpretation of the dimensions in the space. In Figure 2 an example of the results can be seen for two of the three dimensions found. The vectors with letters are the Principal components and the preference (can be separated by the letter at the end of the vector). Looking at Figure 2, it may be seen that the vectors confirm that the previous interpretation of the dimensions is correct, and add additional understanding of how the sounds are perceived. With sounds that are not are synthesized, this methodology will provide a good overview of the properties of the sounds. Moreover, Figure 2 clearly shows what direction to alter the sound in to increase the preference. In this way the MDU method may be used to predict consumer preference on basis of sound characteristics and sensory ratings of these characteristics.

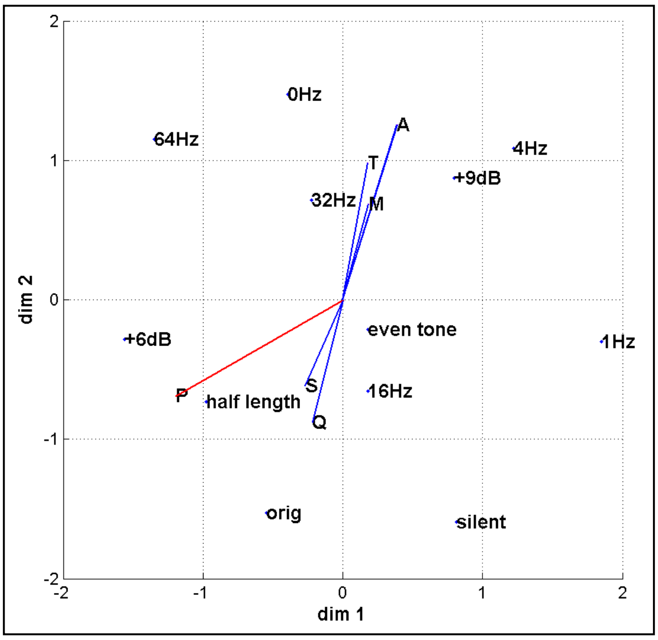

Figure 2: MDU analysis represented as vectors positioned in the middle of the graph.

This method may also be used to predict preference to sounds not within the original data set. A new sound can be mapped into the "space" (in terms of physical characteristics) and its relation to costumer preference can be derived, without having to perform step 3 in the test design. This is advantageous since preference mapping with customers require many listeners, which makes it time-consuming and costly. Of course the database of sounds have to be updated from time to time since this model does not predict changes over time. Furthermore one has to keep the sounds in the model specified for one segment, comparing widely separated test items will not show any relevant results.

Conclusions

This research shows that MDU is a useful method that can be used to niche product sounds and a good way to find a goal-sound toward which the product development should aim. The advantage of this method is that the sound environment gets more customer oriented, without the need to have customers present in all steps during the development. This will make the final product more competitive in the final market.

References

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