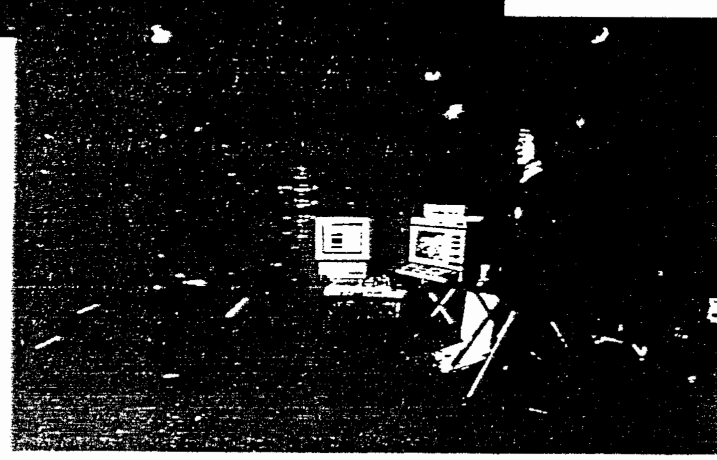
SOUND QUALITY: A NEW PARADIGM IN PSYCHOACOUSTICS; PART ONE

By Steven J. Orfield

Sound Quality, informally defined as the psychoacoustic study of the listener's positive and negative responses to sound, is an interesting case of acoustical practice crossing many disciplines.

Sound Quality Jury



Sound Quality Editing

While the tendency within science over the recent past has clearly been toward specialization, a more current paradigm within many of the specialties has been toward a more integrated general view of problems from the point of reference of many disciplines rather than one.

This interest in multiple points of reference with regard to a given problem has been very clear within the fields of acoustics, audio engineering, audiology, physiology and psychology. While most of these fields have been insistent on their origins in physics, they are now becoming increasingly convinced about the utility of resolving many of their problems within the social sciences, and more specifically, with the field of the psychology of perception. This move from the traditional sciences to the social sciences has long been predicted and is now well underway.

While the judgment of acoustic phenomena has generally been based on the analysis of the source, it is now moving inexorably toward analysis of the receiver — or listener response. This article is not a research overview, but is rather a brief introduction to the concept of sound quality. It is not specifically oriented to the audio field but rather deals with basic acoustical sound quality concepts.

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THE FIELD OF SOUND QUALITY

Sound Quality is an emerging field that is currently most strongly applied in one industry, automobiles, and this serves as a partial basis for its discussion. From the design of the Miata sports car to a Ford Taurus sedan to the increasingly sophisticated audio systems being installed in cars, the question of how the listener perceives sound has become central to automotive design. Recently, Ford Motor Company gave its highest annual employee honor to the developer of a sound quality program for that manufacturer.

In general, sound quality suggests these types of questions:

- How pleasant does the product sound?
- Does the sound suggest power?
- Does the sound seem appropriate for

Sound Intensity Mapping

Modal Analysis Testing

the product?

• Does the product sound expensive?

• Does the product sound annoying or peculiar?

The intent of the acoustical staff and the allied market researchers in the sound quality field is to characterize various parameters of listener response to products and to then optimize the acoustical performance of the specific product in accordance with these positive and negative response parameters.

It is interesting to note that these user preference parameters are often well correlated with very limited market segments. For example, the sports car enthusiast buying a new Porsche generally wants the car to sound powerful and responsive. He may even identify the sound quality as 'sounding like a Porsche' if he has had previous experience with this car.

The same set of qualities may well be described by a more typical driver as rough and unpleasant. Thus, sound quality has a clear interest in the expectation of the product purchaser and other potential users.

Another issue with considerable bearing on sound quality is that of environmental impact. Whether the product is a subwoofer installed in a typical condominium or a lawnmower in a residential neighborhood, the strongest sound quality response may be from someone other than the product owner or user, and this response is generally characterized by annoyance. Therefore, a product may need to have two levels of sound quality performance: in the near field (close to the user) it should produce a sound that meets the user's expectations, and in the far field it should produce a sound that has little or no negative response from other listeners. There are many products which are in need of this double sound quality definition.

THE QUESTION OF HOW THE LISTENER PERCEIVES SOUND HAS BECOME CENTRAL TO AUTOMOTIVE DESIGN.

An additional issue in describing the designed sound quality of a product may be the time or place of use. The 'sports car' sound may be suitable for the open highway but far less suitable on a residential street at night. As a result, there may be some rationale in developing 'adjustable' sound quality devices, such as active electronic mufflers.

Another issue in the sound quality field is the issue of the 'natural response' of a product. While many products produce 'positive' sound qualities as part of their inherent operation, in some cases, the ideal sound quality of a product may have to be synthesized, as the product itself cannot be 'tuned' to produce this sound. An example in vehicles may be the installation of a concealed audio generator to provide or enhance the overall sound quality of the vehicle. This is an interesting case in point especially when the near and far field requirements for sound quality are substantially different.

SOUND QUALITY METRICS

Psychoacoustics has long supported the development of metrics and calculations to describe the individual's response to acoustic sources. Some of the better known among these are environmental acoustics metrics, such as Ldn, Noise Pollution Level and Effective Perceived Noise Level. In the audio and architectural acoustics fields, there is the articulation index, AL%cons, and some of the more sophisticated quality descriptors of rooms, such as lateral fraction and C and U values. Bridging to the field of audiology are calculations such as Speech Transmission Index.

Of particular interest to the sound quality community is the work of Zwicker and Fastl, most recently incorporated into their 1990 work, *Psychoacoustics, Facts and Models*. In this classic work, Professors Zwicker and Fastl expose a long history of work in attempting to define specific characterizations of sound, such as loudness, sharpness, pleasantness, fluctuation strength, roughness and subjective duration. There is now work ongoing to develop methods of sound quality analysis, using these calculational tools as an adjunct to quantitative jury experiments. (Further information will be available in the continuation of this series.)

THE SOUND QUALITY PROGRAM

In the actual applications engineering of a product, sound quality is generally a multistep program from inception to completion. SQ programs generally include the steps outlined in Table One.

TABLE ONE

Sound Quality Standards Development
- Product listening and market discussion
- Market research
- Binaural Recording of current and competitive products
- Playback to a listening jury
- Calculation of sound quality parameters
- Editing of sound to reduce annoyance and increase positive sound quality based on jury response and calculations
- Playback to a listening jury of alternative solutions for validation.

Sound Quality Initial Measurement
- Playback and measurement of above recordings
- Application of alternative analyses of time and frequency-based components
- Characterization of acoustical performance at all points of operation (speed, cycles, etc.)

Sound Quality Localization Measurement
- Sound Intensity measurement based on measurement findings and targets for reduction in sound components
- Sound Intensity measurement of components of the product under test often with product covers removed
- Sound Intensity mapping of sound power over engineering diagrams of product surfaces

Sound Quality Modal Measurement
- Modal Analysis measurement based on measurement findings and targets for reduction in sound components

Sound Quality Prototype Development
- Production of an operational prototype based on sound quality standards and measurements

Sound Quality Jury Presentation
- Binaural recording of prototype
- Presentation of recordings to jury
- Presentation of actual product to jury
- Market research on prototype

A hypothetical case may serve to illustrate the process. A washing machine manufacturer may be interested in evaluating the sound quality of one of their products, with the fact in mind that washers are considered noisy. A number of questions may follow:

- *Is our washer louder than other competitive products?*
- *How much louder than the background noise level is the washer? (background level in area of use)*
- *Is it important that the washer provide any noise level as a cue to the fact that it is operating?*
- *Are some cycles on the washer more annoying than others?*
- *Does the washer need to have a higher sound quality definition due to its increasing use in kitchens and upstairs areas?*
- *Should the washer only run at certain times of the day? (i.e., does it have a timer?)*

Given this information, the manufacturer would normally want to validate the consumer response with some type of focus or quantitative jury session. This may begin with consumer discussions first, in order to determine if the consumer has any strongly expressed feelings about the noise of the washer. (Since market research experts often consider focus groups to be quite unreliable, this step is increasingly left out.)

After this step, recordings are often made of the product under test and of directly competitive products. These recordings are often played back to the acoustical staff to develop some initial opinions of comparative sound quality, and measurements of overall noise level are often taken at this time. Also, some sound quality calculations may be made at this time to attempt to predefine the problem areas of the recordings.

Next, consumers are generally assembled into a listening jury representing the demographics of typical product users. They are presented with a number of recordings of washers, comparing the overall response to each product and comparing the cycle-by-cycle sound quality ratings of the individual products. (Sometimes, this consumer jury is also presented with visual stimuli, such as a video of a washer running.)

Based on the results of jury testing, the recordings are transferred to a digital editing system in order that changes can be made in the product to reduce negat sound qualities and to enhance posit ones.

The jury is again assembled, and clos spaced presentations of alternative edit sections are presented for quantitat rating. After a series of these jury rat sessions have been completed, a sou quality standard is then assembled as design goal.

Once negative sound qualities for t washer are determined, testing must completed to locate the source of the qualities, and this is generally done via t use of sound intensity measurement a contour mapping. Each face of the prod is generally mapped under operating co ditions, and these data are then plott over engineering drawings of the prod in order to locate the source of the spec noise components producing the offend sound qualities. This will often result quick identification of the specific co ponents which can then be redesigned order to reduce the offending noise.

In some cases, the offending noise i result of the resonance of specific comp nent parts, such as pulleys, shafts, etc. those cases, a second stage of analysis often undertaken, and that is order a modal analysis. Via this analysis, the co tribution of a single structural item can analyzed, and the 'ring' or resonance this component can be changed changes in materials, material density, s fening, etc.

Finally, many new analysis tools coming on line, including non-station signal analysis tools, such as the wave transform.

After these efforts, measurements continually made to detect variations in t noise components of interest which h resulted from the change. Once the pr uct begins to approximate the sound qu ity definition, then recordings are of repeated along with quantitative ju testing.

In the case of a washer or similar co plex product, the full schedule of sou quality procedures may span from betwe a few months to design cycles of yea

SOUND QUALITY — AREAS OF INTEREST

Currently, there are very few firms in the United States with full sound quality programs capable of analysis, jury work, product diagnosis and product alteration. The concept is currently being applied principally to consumer product design by manufacturers, but its potential is far broader.

Other areas of involvement that are promising are architectural acoustics, audio product design and systems engineering, hearing aid design and testing, environmental noise evaluation, and medical diagnosis.

THE SOUND QUALITY WORKING GROUP

Since sound quality is new to most interested acoustical professionals, it is difficult to find information on firms involved in the field who are testing systems suitable to the field and providing outside consulting assistance. With this in mind, Orfield Associates recently formed the Sound Quality Working Group, an organization of specific firms who are interested in supplying products for sound quality evaluation and services, such as seminars, training and support services. In addition to Orfield Associates, this group includes Bruel & Kjaer Instruments, supplier of acoustic test instrumentation, TEAC Industrial Recorders, suppliers of precision acoustic DAT recorders, Yamaha Professional Audio, supplier of audio processing components, and Sennheiser, supplier of headsets. In addition to these members, National Instruments is providing support for the development of sound quality sof ware and interfaces to accept data fror analyzers and download to PCs for calcula tion and analysis.

The first three of these manufacturer have previously joined sponsored researc into the development of binaural recordin systems (see Sound & Communications Sept., Oct. 1990) and the fourth has jus introduced a new line of headsets targete toward the binaural listening environmen (All of these manufacturers will be provic ing their products through their norm sales representatives.) After much discus sion and preplanning, the Sound Qualit Working Group held its initial meeting i Minneapolis on January 23, 1992, and Sound Quality User Group is now bein organized for interested users and poter tial users of this technology.