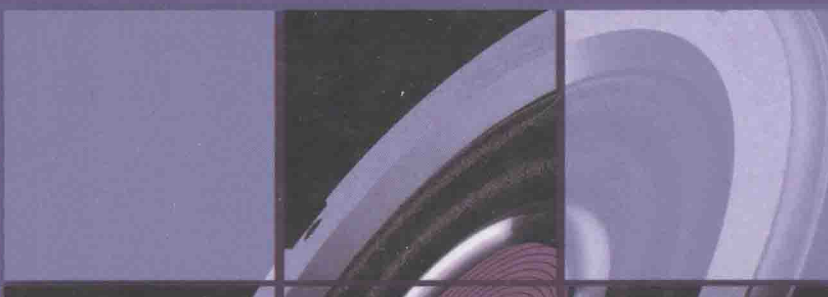
2014
电声技术新进展
——ISEAT会议论文集

沈勇　编



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内 容 简 介

本书介绍了电声技术的研究新进展，内容涉及空间声学、耳机、微型扬声器、扬声器单元、扬声器系统、电视机声学性能、测量方法、信号失真、信号处理等领域。全书由国内外数十位电声领域的知名专家和工程技术人员共同完成，涵盖内容较广，具有很好的实践指导意义。

本书可作为电声技术领域的科研人员和工程技术人员的参考用书，也可供普通高等院校电声专业的教师、研究生阅读和参考。

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前　言

电声学所涉及的领域不仅是声学、电子学等学科，而且跨越科学与艺术两大领域，实用性很强。电声技术广泛应用于通信、消费电子、计算机、影视、建筑、音乐、娱乐等领域。在国际上，电声领域的发明创造大量涌现，科技成果不断应用并转化为新的生产力。电声技术在增进人们交流、提高生活质量、改变生活方式、提供就业机会等方面发挥着十分重要的作用。近年来，中国的电声企业在国际上表现出众，显现了中国电声企业正在从大变强。

为了加大具有国际水平的电声技术交流平台的建设力度，2013 电声技术国际研讨会（ISEAT2013）在深圳虚拟大学园隆重举行。会议由南京大学声学研究所、近代声学教育部重点实验室主办，中国电子元件行业协会电声器件分会、中国声学学会/中国电子学会声频工程分会、深圳虚拟大学园管理服务中心、《电声技术》期刊、瑞声科技控股有限公司协办，南京大学深圳研究院、南京大学声学深圳研发中心承办。作为 ISEAT2013 主席，我荣幸地邀请到数字音频革命教父——Barry Blesser 博士、AES 理事长 Sean E.Olive 博士、Linda-Ruth Salter 博士、Wolfgang Klippel 教授、Mark Dodd 先生等多位国内外享有盛誉的著名科学家、教授、资深技术专家，以特邀报告、知识讲座等方式在电声技术多个方面进行了交流研讨。

ISEAT2013 吸引了来自美国、德国、英国、日本、丹麦等多个国家以及国内多个省市和香港、台湾地区的 200 多家单位，共计 600 多人参加。

本书的内容包括综述、空间声学、耳机、微型扬声器、扬声器单元、扬声器系统、电视机声学性能、测量方法、信号失真、信号处理等。

21 世纪电声产品的设计需要采用一种跨学科的方法，包括社会心理学、神经心理学、营销策略、行为经济学、进化心理学和文化人类学。数字音频教父、原 AWS 理事长、AES 银质奖章获得者 Barry Blesser 博士认为设计应以人类大脑为基础，并且列举了几个相关的实例，对其进行了详细分析。

AES 理事长 Sean E.Olive 博士长期致力于新型音频产品的主观评价研究。大学生是耳机的主流消费群体，然而关于大学生在耳机声音品质偏好方面的研究还没有任何成果发表。本次会议上，Sean E.Olive 博士精彩讲述了大学生和专业受训听音员在耳机声音品质偏好方面的比较。

Linda-Ruth Salter 博士一直专注于建筑环境的心理学体验研究，并致力于将人文社会科学与科学技术整合起来的研究。在本次会议上，Linda-Ruth Salter 博士从声源、环境、听众三个角度分析听音体验，解读听音体验的实质。在此过程中，Linda-Ruth

Salter 博士创造性地提出了“声环境”这个全新概念，更好地解释了声音与空间的关系。

德国德雷斯顿工业大学电声学教授 Wolfgang Klippel 博士在《微型扬声器的大信号特性》一文中介绍了一种非线性扩展模型，以描述非线性失真的产生，并介绍了一种新的动态测量技术：通过音圈速度 v 测量非线性阻抗 $R_{ms}(v)$。通过实际测量微型扬声器的非线性失真，将实测结果与非线性模型推导出的结果作对比，验证了文中的理论及测量技术，为微型扬声器的非线性失真分析提供了强有力的工具。

GP 声学集团研发团队总监 Mark Dodd 在《同轴驱动的两分频紧凑型扬声器系统的发展》一文中，通过与 BBC 的经典扬声器 LS3/5a 进行比较，对 KEF 公司的一种采用最精致同轴驱动技术的紧凑型两分频扬声器系统进行了阐述，文章简明讨论了自 1970 年早期以来建模和测量技术的发展，总结了用于新型扬声器系统的驱动技术，阐述了集中参数模型、有限元模型和边界元模型在新型扬声器设计中的系统应用，提供了大量的模拟结果，用于展示新的设计和建模方法。从扬声器系统的整体到细节部分都进行了划分，每个部分都进行了详细描述，并通过仿真展现，包括对箱体和端口的设计和改进，对于衍射和驻波的控制等。这对于扬声器系统的设计者和对扬声器系统设计感兴趣的研究者都有极大的帮助和实际意义。

本书得以出版，要特别感谢全体作者的共同努力。我衷心希望本书的出版对促进相关领域科技人才的成长和科研水平的提高、促进经济的繁荣和发展有所贡献。

南京大学声学研究所 沈勇

2013 年 11 月于南京

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综 述
Review

An Objective Measure of Quality is a Cognitive Illusion

Barry Blesser[1] Linda-Ruth Salter[2]
(1,2 Blesser Associates Belmont, MA 02478 USA)

Abstract When designing electro-acoustic products, high-quality sound has been the central goal. However, recent research shows that what we think of as objective "quality" is actually subjective "preference." While technical quality is a property of the external product, subjective preference arises from an individual's emotional mood, cultural biases, cognitive state, social context, personal history, brand identity, and familiarity. Recent brain scans confirm that many neural modules contribute to preference decision-making. Consider an example of the decoupling between quality and preference. When the Boston Symphony Hall was built in 1900, its acoustics were considered a failure; decades later those same acoustics were judged to be of the highest quality. The hall did not change; the audience became familiar with its new acoustics. A listening experience is actually a system composed of acoustic and human elements, each of which has its own unique rules. Objective "quality" is an illusion.

Keywords subjective preference, cognitive, objective measure

1 Introduction

There are personal and economic rewards for delivering electro-acoustic products that will be successful, which means that the public will select, use, and enjoy them. Such

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products are often called *high quality.* Since this phrase is used in a wide variety of situations, we need to explore its real meaning.

1.1 What does the Word *Quality* Mean?

When two individuals attempt to communicate about a topic, they assume (a) that they are speaking about the same thing, and (b) that words have an unambiguous meaning. We are so confident that meanings are shared that we rarely define the words that we use in conversation or documents. However, linguists have shown that the assumptions about word meanings need to be carefully examined[1-2]. The meanings of words change over time, across geographic distance, and especially among different cultures. Moreover, differences in meanings can appear even between two individuals who appear to be very similar; people have different values, goals, and experiences. We argue that the word *quality* has multiple (and sometimes contradictory) meanings that exist simultaneously.

In the Western technology context *quality* means that if a product has more of a particular technological attribute, it is of *higher-quality,* while a product with less of this technical attribute is of *lower-quality*. For example, an audio amplifier with a 30 kHz bandwidth has superior frequency handling ability as compared to one with a 15 kHz bandwidth. Bandwidth is the attribute, and the designations of *high quality, low quality,* or *superior quality* represent the relative rankings of audio amplifiers according to the amount of a measurable attribute. This type of quality evaluation uses attributes that are objective, observable, and measurable. Typically, product-specifications documents contain dozens of such attributes with their numeric values.

Engineers also know that quality ranking gets complicated with products that can serve multiple functions; the ranking can be inconsistent across attributes. For example, one capacitor may be ranked higher than another for its voltage rating, but lower for its tolerance. Which capacitor is of *superior quality*? There is no absolute answer. It depends on the how the capacitor will be used. When the phrase *high-quality* is applied to a complex product with multiple attributes that are used in different situations with different purposes by different people, the meaning of *high-quality* is ambiguous. In a discussion between two design engineers, the underlying assumptions about the meaning of *high quality* may not be shared.

Let us expand this example and compare the meaning of *quality* in a discussion between a design engineer and a product marketer. These two individuals may share many characteristics and have a common language, but they each come from unique corporate cultures that differ in the way that they view a product. The design engineer determines *high quality* according to objective and measurable design specifications using formal laboratory protocols. The marketer determines *high quality* according to the preferences and choices made by the consumer. The marketer's attributes are subjective, changeable, and difficult to measure.

The design engineer and the marketer inhabit different cultures, and they each have a different meaning for the word *quality*. From the point of view of the design engineer, the marketer's definition is illogical and unreasonable—customers should prefer products that have more of a particular technical attribute. Why chose a less powerful product just because it has a particular shape? From the point of view of the marketer, the design engineer is being rigid—the shape may well be more important than the expanded bandwidth. The meaning of *quality* is neither obvious nor easy to discover. To assume that a given design is of higher or lower *quality* without examining the values and assumptions underlying the meaning of the word can lead to confusion, and the resulting products may be financial failures.

1.2 Subjective Preference is More Useful Concept

We suggest that *subjective preference* is a more useful concept than *quality* when it comes to developing and evaluating a design. In the end, the success of a product is determined by how many individuals choose to purchase it. An individual creates a preference by an internal neurological processes that is personal, intuitive, emotional and most of all, not conscious. *Preference* becomes clear only when we observe the behavior of people, while *quality* is a physical attribute of an object that can be measured.

The relatively new field of behavioral economics focuses on the psychology of subjective decisions[3]. The brain combines thousands of pieces of information and then produces a single decision. Engineers are often surprised that *quality* and *preference* are decoupled. A design that scores high on measurable attributes might score low on attributes that relate to human choice behavior. What is quality to one person or group might not be quality to another. For this reason, *preference* and *quality* across individuals and groups do not align.

1.3 Cognitive Science and the Marketplace

The remainder of this paper explores the ways in which people make preference decisions; these decisions take place in the hidden modules of the brain. Understanding the process of decision-making requires another type of paradigm, one that is unrelated to the paradigm used by technologists who characterize physical objects. A technical paradigm has rules of causality, repeatability, quantification, consistency, and so on. A human decision-making paradigm has rules that relate to people's brains, which are determined by their unique personal and social history.

The brain follows its own rules, which has nothing to do with scholarly concepts of logic, reason, stability, and consistency. Moreover, this complex process of decision-making takes place beneath consciousness. Human beings are the result of millions of years of evolution; there was no designer of the brain. Our brains evolved in an ancient ecological environment that has nothing to do with modern society. Our task is to articulate how people actually behave, not to describe how they should behave in some idealized world. Researchers are only beginning to understand the unconscious brain.

Those who understand and appreciate human decision-making are more likely to have successful careers and to be part of a thriving company. Even in a technical context, understanding people raises the likelihood of a product being successful. Applying cognitive science and neurobiology to the design process is the next frontier. Integrating these new concepts requires an alternative way of thinking: becoming multi-disciplinary and multi-cultural. Consider a loudspeaker equalizer from both the perspective of a signal processing engineer and a cognitive psychologist; consider it from the perspective of a teenager in Berlin and a violinist in Boston.

Using cognitive science in a commercial context does not replace the technical skills that have already been accumulated. A successful product still needs to be designed by experts who use the best practices in achieving their technical goals. The attributes of a product must meet the technical specifications. However, for the 21st century, additional considerations will be needed to be successful. Technical expertise is too widespread to remain the deciding factor in separating the winners from losers. At one time, only a few specialists could create complex electro-acoustic products because the required technical skills were scarce. This is no longer true. Globalization has distributed technical knowledge to the four corners of the earth with the resulting intense competition that drives profit margins to very low levels.

During the last few decades, advances in cognitive science have had a profound influence on many different disciplines: economics, religion, education, laws, justice, ethics, politics, marketing, social policy, and many others. Our discussion expands the traditional engineering views with an additional way of thinking: understanding how our evolutionary brain functions in the commercial market of electro-acoustic products. We argue that cognitive science should be an additional tool in the specification, design, manufacturing, and sales of electro-acoustic products. The 21st century will be the era of understanding inner space—the life of the mind in everyday life.

1.4 Products have Personalities

A product's personality is fundamentally different from its technical specifications and requires a new way of thinking—a new paradigm. We would like to introduce the idea of a new paradigm with a few quotations from Albert Einstein, one of the scientists involved in creating a new framework for physics.

- A person should look for what is, and not for what he thinks should be.
- The sign of intelligence is not knowledge, but imagination.
- Everything that can be counted does not necessarily count; everything that counts cannot necessarily be counted.

Product personality is based on who will be using the product, and how they will be using it. What are the social, cultural and physical contexts within which the product will be placed? What are the values and previous experiences of users? What is the meaning of the product within the user's culture? What problems will the product address, and what are the relative cultural values of these problems? Product personality takes into account properties that are holistic, intuitive, interactive, emotional, and variable.

The decision by the consumer to use or reject a product is based on hidden inner workings of the brain rather than on measurable specifications. A product's personality has a strong influence on how potential users will feel, and feelings are a major component of preferences.

2 How the Brain Works When Making a Decision?

All aspects of human behavior originate from the neurological activities in the brain. A successful product is the result of millions of brains making the decision to acquire it. In order to understand how preference judgments occur in the brain, we need to explore some recent research in cognitive science, neurobiology and evolutionary psychology.

2.1 Brain Activities are Tagged with an Evaluation

Let us begin with a simple model of how the brain makes decisions. Deep within the mammalian brain there are hundreds of neurological modules that process external and internal stimuli. For a guided tour through the modules in the brain, see[4]. These modules are specialized pieces of neurological machinery that have been optimized for particular operations; they are continuously communicating among themselves in order to produce a complete picture of the world and to then select the behavior that maximizes survival and safety. At any instant, however, only one or two of these modules can produce an action.

How does the brain decide which of the hundreds of stimuli should produce an action? The brain gives every stimulus a "tag" indicating the degree to which that stimulus is good (safe or pleasurable) or bad (dangerous and fearful) for the person. Tags are the result of personal associations to previous experiences combined with information about the external world. Based on these tags, the brain makes a determination about whether a given stimulus represents safety or danger. Tags are first sorted according to which stimulus is the most dangerous. That tag is then sent to action modules, which produce a behavioral response. Examples of stimuli that receive the danger tag are the smell of smoke, the sound of an explosion, the sight of an angry face, or a corporate memo describing a manufacturing failure. Negative tags lead to one of three responses: flight, fight, or freeze.

In contrast to a stimulus with a negative tag, a stimulus with a positive tag leads to the behavior of wanting more of that stimulus. We approach stimuli with positive tags. For example, we walk towards a person with a smiling face, or we move toward the smell of food. Customers select products that create brain stimuli that receive positive tags: wanting to have more of such experiences.

How does the brain assign tags to elements of new experiences? It associates to previous experiences. As a hypothetical illustration of how a positive tag develops, consider the following. The president of a company has been wearing green shirts for decades. The color green acquires the association of success, power, fame, and status. Other green objects are associated with the president's green shirts, which is associated with power. The company's logo is green; trade-show clothing is green. As illustrated by IBM, which is still called "big blue," color can have acquired meaning. Such associations may not be logical, but they are biologically efficient.

Consider a real example how attributes are associated. In the late 1950s before transistors were introduced, the best audio amplifiers were extremely heavy. They used vacuum tubes and large transformers. Weight was an indicator of the mass of the core in the transformer, and that was an indirect measure of its ability to handle power and frequency. The conversion to transistors produced much smaller amplifiers that were light and without transformers. But customers associated the lack of weight as meaning that the new amplifiers lacked substance and quality, and the new amplifiers were not readily accepted. Manufactures responded by adding lead weights to bottom of their chassis to take advantage of the associations between weight and quality. Like the color green, the attribute of weight acquired an associated meaning from previous experiences. These associations can strongly influence preference decisions in the marketplace.

These examples illustrate that the brain has its own logic. The neurological processes that create associated linkages of attributes evolved with our ancient ancestors. Sorting tags and linking their associated properties is biologically efficient. This process is still operative in modern society even among those with advanced technical education.

2.2 Fast Brain Modules Versus Slow Brain Modules

In the transition from primate to humans, we evolved more sophisticated thinking modules, such as the prefontal cortex and anterior cingulate cortex. These advanced modules are able to contemplate stimuli before acting but thinking is a slow process that takes significant effort and time. The brain is a biologically expensive organ that consumes a large percentage of nutrients. Brains get tired. Thinking takes work. As a result, the slower thinking process is used only when absolutely necessary. If our brain had to carefully evaluate every stimulus, we could not drive an automobile or walk down the street. Every sensory stimulus—every object in the visual scene and every sound in the environment—would have to be carefully evaluated using previous experience with similar stimuli. Kahneman[5] explores the types of activity that result from the fast and the slow parts of our brain. His conclusion is that most of life is controlled by the fast and intuitive brain modules; the slow-thinking brain is rarely used, and when it is operating, it does not always produce the best action. The slower contemplative brain modules play an important role in advanced professions, such as solving a differential equation, but the fast unconscious modules are also playing a role in those same situations.

This description of the brain is very simplified but sufficient to give us a feeling for the decision-making process. Some brain modules receive stimuli directly from the senses. The information in these stimuli combines to form a model of the outside world. Other parts of the brain assign a brain tag: safe/dangerous, like/dislike, comfort/discomfort and so forth. The associations produced by these tags then result in a preference judgment, which is translated into a decision, which creates an action. This all happens almost instantly. It takes place outside of awareness or consciousness, and any rational attempt to understand or explain an action is imposed after the process is completed.

Consider the activity of shopping at the market. When looking at dozens of choices for soap, the high speed brain simply picks the one with the strongest associations to pleasure, comfort, and safety. We do not engage in a research activity to evaluate all of the possible choices for soap. I know that I prefer the soap in the large red box because I see my hand reach for it. I am not aware of the internal processes – reception of stimuli, tagging, preference judgment, decision—that moved my hand to that box of soap. Moreover, if asked why I picked that choice, another brain module creates a story to explain that

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