The Role of Critical Listening in Evaluating Audio Equipment Quality

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Abstract

Subjective critical listening can reveal aspects of audio equipment quality not exposed by traditional objective methods. Subjective listening impressions, however, are often unfairly dismissed as mysticism, even when conducted by conscientious, technically oriented practitioners.

This paper outlines the methods and underlying philosophy of professional critical listening, explores the reasons why subjective listening is rejected by the scientific audio community, and draws the distinction between serious listening and pseudoscientific claims.

Introduction

"To doubt everything or to believe everything are two equally convenient solutions; both dispense with the necessity of reflection." Jules Henri Poincare´ as quoted by Bertrand Russell in the preface to *Science and Method.*

This Audio Engineering Society Convention's theme, "Audio Fact and Fantasy: Reckoning With the Realities," reflects a conflict not found in other scientific endeavors. The disparity of approaches between those who believe measurement can quantify every aspect of a phenomenon (the quality of an audio component), and those who rely on direct experience (trusting the ear as a more sensitive and meaningful indicator of audio equipment behavior) is unique to audio engineering.

The division between so called "objectivists" and "subjectivists" - dubbed "The Great Debate" - is particularly deep. To the objectivists, those who use the listening experience to judge reproduced audio quality are considered "charlatans" (1), believers in "astrology" (2), and "think the earth is flat." (3) Indeed, the letter from this convention's chairman inviting members to submit papers referred to subjective listening observations as "fantasy." (4) Furthermore, there has been a campaign to discredit any kind of critical listening evaluations by speciously associating them with a rejection of physical laws and established scientific fact. (5)

To the subjectivists, the audio engineering community is made up of soulless technocrats whose narrow and rigid world view excludes a sensitivity to the subtle, yet musically significant, differences between audio components - differences that it appears cannot be measured with existing technology. The objectivists are viewed as bound by theoretical dogma and refuse to accept the reality of direct experience. The objectivists' claim that no sonic differences exist between competently designed and manufactured audio components (or those having similarly good measured performance) is an absurd premise that is anathema to the experience of hundreds of thousands of critical listeners.

Thus the lines of division are drawn.

Any inquiry that attempts to shed light on "The Great Debate" must address the underlying issues rather than rehash the same tired arguments. Although it is useful both to state unambiguously the subjectivist position and to demystify the methods for those with misconceptions of subjectivist techniques and ideology, a more fruitful approach examines the root causes of the conflict. Indeed, the entire issue is symptomatic of the question of science's capacity to encompass within its domain all forms of knowledge.

In addition to presenting the basic tenets and methods of subjective critical listening, I shall attempt to go beyond the traditional battlegrounds and establish a wider framework for the debate.

My profession gives me a unique insight into this conflict: I am a full-time professional reviewer of so-called "high-end" consumer audio products. The magazine for which I write publishes critical analyses of audio components, including both subjective impressions and measured performance. My job is listening to, and measuring, audio equipment. In the course of my work, I listen extensively to audio components and measure their technical performance in the magazine's test laboratory.

My experience overwhelmingly indicates that many aspects of audio equipment quality are revealed in the listening room and not in the laboratory. Ironically, this simple thesis will be regarded by some audio professionals as a given truth and unworthy of debate, yet others will denounce it as heresy and a threat to science's role in advancing audio engineering.

This paper will explore why.

Subjective Critical Listening: Methods and Criticism

"Whenever connoisseurship is found operating within science or technology we may assume that it persists only because it has not been possible to replace it by a measurable grading." - Michael Polanyi, *Personal Knowledge*

Subjective critical listening is an integral part of every facet of audio. From the recording engineer who selects microphones based on an evaluation of their sound to the consumer choosing loudspeakers in a showroom, the subjective critical listening experience exerts an enormous influence on the field of audio recording and reproduction. At every stage in the recording process, countless value judgments are made about the quality of perceived sound. Similarly, hardware designers engage in an iterative process of designing and listening to realize the best performance from their products. (6)

No one doubts the necessity or utility of subjective listening. Yet it seems that value judgments of sound quality expressed in print during a product review are criticized as capricious, fantasy-inspired, invalid, or influenced by external variables, while value judgments made at every other point in the chain are accepted without question. Indeed, audio equipment reviewers are singled out for criticism by objectivists - "the journalistic elite" (7) - perhaps because of those reviewers' rapidly growing following and influence.

Contrary to the objectivists' misconceptions, much subjective critical listening as practiced by magazine reviewers is conducted under carefully controlled conditions - more controlled, in fact, than the conditions present during many other stages in the music recording and reproduction process. I cannot speak for other magazines, but my own listening, (and that of my colleagues who write for the same publication) is anything but casual. Of our nine most prolific reviewers, seven have gone to the trouble and expense of having a dedicated listening room. Their residences were often chosen on the basis of their listening suitability, or, in the author's case, the listening room was purpose-built from the ground up. In addition, the magazine also converted and acoustically treated a room at its Santa Fe headquarters specifically to perform listening evaluations.

Careful controls are also maintained during subjective critical listening. Levels between components under audition are matched to 0.1dB or less. Linear differences, such as whether the unit is polarity-inverting or not, are accounted for. Listening sessions are conducted virtually daily for weeks or even months before the review is written. A wide range of familiar source material is used over long periods of time and over a variety of equipment, precluding the possibility of ascribing a particular characteristic to a component that is actually a characteristic of the recording. Many of my colleagues are active recording engineers and use their own recordings in evaluating equipment. Some are musicians, daily exposed to the ultimate reference of live, unamplified acoustic instruments. All of us became reviewers because of our lifelong dedications to music and music-related technology. All of us take our responsibilities to our readers - and to audio truth - very seriously: our attitude is the antithesis of caprice or whim. When one chooses a profession out of a desire to contribute to a particular field, one tends to make the performance of that profession a large part of one's life. Indeed, the content of this very paper exemplifies an approach to subjective reviewing that is anything but cursory, "casual," or superficial.

The "single presentation method" is the preferred technique of assessing a component's quality. In this method, the component under review replaces a component in a known reference playback system, and the reviewer spends weeks or months listening to music through it. The same level-matching controls and awareness of relative response errors are used as in direct comparison listening. Although some A/B comparisons with other known or comparably priced components are made, the single presentation method is the best way to determine the long-term quality of the component in question. (8)

In addition, the component under review is measured - with industry-standard instruments like the Audio Precision System One and DRA Labs' MLSSA - to find possible correlations with what we hear. Measurements are also useful in revealing a particular product's idiosyncrasies that might make it a poor choice for use with specific components. (An amplifier that lacked the ability to deliver current into low impedances, for example, would not be recommended to drive ribbon loudspeakers.) The objective, measurable differences between products are fully researched, understood, and given significant attention in the review.

Indeed, these controls on the subjective listening sessions and the technical examination of a component are often far more rigorous than the procedures used during the making of the very recordings and equipment under evaluation. If one reads the objectivists' criticisms and dismissals of subjective critical listening, however, one is led to believe that listening evaluations are sloppy, haphazard, casual, and with no regard for the subjective differences imposed by easily explainable objective differences. According to this argument, the differences heard between components are nothing more than differences in level or frequency response - objective differences to which subjective reviewers are supposedly oblivious. Further, subjective listeners are often characterized as technical know-nothings operating from platforms of ignorance. (9) That may sometimes be the case, but the technically competent and conscientious critical listeners should not be condemned by association. Just as there are varying levels of competence in any field, an entire philosophical position - the validity of listening - cannot be summarily dismissed because some of its practitioners fail to uphold the highest standards.

Subjective critical listening as practiced in product reviews is also attacked because of alleged reviewer bias. In my own work (and that of my colleagues), the positive or negative tone of a review is based *solely* on the component's sonic performance, not size, faceplate thickness, cost, brand, reputation, whether or not the manufacturer buys advertising, or other alleged variables. Although it must be admitted that, before any listening, an expensive product from a reputable manufacturer will be expected to sound better than an inexpensive product, any such preconceptions vanish when the products reproduce music. The listening experience is the sole criterion by which a product is judged. Other factors - construction quality, compatibility with other components, value for money, and

ergonomics - play minor roles. Only a component's sound quality - its ability to convey the music - determines the positive or negative tone of a review. It is not unusual for a product from a company with an excellent reputation, carrying a high price and having good construction, to receive a negative review, or for a low-priced product to receive a favorable assessment.

Furthermore, there is a high degree of correlation between the descriptions of a particular component's sound between reviewers in different magazines and different countries[1]. Reading several reviews of the same product - reviews often published simultaneously - often reveals a clear consensus about the component's specific sonic attributes. This evidence that components indeed have unique sonic signatures is dismissed by the objectivists who allege premeditated collusion among the world's audio journalists. In the case referred to, there was *no* such collusion and given the normal magazine lead-in time before publication of two months or more, no chance for a reviewer to have been influenced by an earlier appearing review by someone else. The resort to conspiracy theories is always the sign of a weak argument.

The entire purpose of subjective critical listening as practiced in product reviews is to discover the sonic and musical attributes of a component and express that opinion to the magazine's readers. The magazine's continuing success is predicated on the accuracy of the sonic descriptions and value judgments as determined by the world at large. The growth of high-end magazines (and their increasing commercial success in a marketplace long dominated by publications reflecting an objectivist philosophy) reflects the concurrence between reviewers' and readers' value judgments[2].

Finally, the question must be asked: Who is better qualified to judge the presence of audible differences between components and the musical significance of those differences - the scientist confined to the laboratory and classroom who refuses to listen for himself, or the professional audio reviewer who makes his living listening day after day under carefully controlled conditions to different components?

Listening vs. Measurement

"One of the worst-kept secrets in audio engineering is that what we hear does not always correlate with what we measure." - Richard Heyser

The belief that nothing more can be known about an audio component's performance beyond the numbers generated by "objective" testing implies that "quality" in an audio component can be unambiguously quantified and expressed by mathematical symbols. Since the entire sum of how a component affects the signal passing through it - down to the smallest detail - is known and measurable, why listen? And since these tests and measurements are completely objective, why interject human subjectivity into the process of determining which audio components have more quality than others?

This objectivist argument is based on two false premises: 1) that scientific inquiry is objective and detached from the individual, and 2) that audio equipment quality can be reduced to a series of mathematical representations.

The first false premise - that objectivity actually exists - is deeply rooted in Western thought. This paper cannot have the ambition of discussing the subject in depth; instead I refer the interested reader to the works cited in reference 10 and footnote 14. However, a glimmer of the underlying fallacy can be seen when examining the concept of objectivity in audio testing. What do we observe objectively when determining what constitutes "good" performance? The color of the resistors? How many cycles of the test tone the component reproduced during the test? The size of the chassis screw threads? Of course not. Of the virtually infinite range of observations of the component under

analysis, some are *chosen* as being greater indicators of "goodness" than others. It is this choice of which tests represent quality that is, in itself, a subjective decision[3]. The formulation of hypotheses is intrinsically subjective; on what basis are some hypotheses chosen over others?

But what is "quality" in an audio component? Is it merely the ability to meet certain "objective" criteria? I think not. I propose that audio equipment quality is irreducible to an arbitrary set of numbers. Audio component quality is defined in the listening room - by its ability to convey the music's essence and meaning without imposing itself on the musical experience. Some components produce an intimacy with the music that makes the listener forget the playback system; others seem to do their best to prevent such an experience. My experience suggests that this fundamental characteristic - perhaps related to the listener's holistic reaction to the reproduced sound - is a far more meaningful indication of audio component quality than a set of numbers produced in the test lab.

More specifically, there are myriad audible differences between components whose causes we haven't begun to understand, much less measure and quantify. Such aspects of musical presentation as soundstage depth, sharpness of instrumental image outlines, sense of space between individual instruments, how well soundstage width is maintained toward the rear of the presentation, and natural reproduction of timbral shadings, are far beyond the abilities of existing technology to measure. (The degree of correlation between the signals in the two channels can be measured, of course, but that is about it.) These are just a few examples of the currently unmeasurable differences between components. This isn't to say that these qualities are somehow mystical because they defy measurement, only that the resolution of today's instruments is below that of the human auditory system. Indeed, most of the measurements in use today were developed decades ago as design tools, not as representations of musical reality. Measurement may one day advance to the point of describing these differences, but that day is probably a long way off.

The advances made in digital audio data-compression techniques underscore the role of subjective critical listening in evaluating audio equipment quality. Data-compression schemes produce huge objective errors in the signal, errors reportedly masked by the correctly coded wanted signal. No measurements exist that reveal the relative quality of data-compression systems: all evaluations are made by critical listeners.

Do we really have the hubris to believe that the resolution of test instruments devised in the last few decades exceeds that of human hearing acuity, refined through millions of years of evolution? The reluctance to admit that measurements fail to quantify all aspects of audio component behavior stems from a reluctance to accept the limits of our understanding, and indeed, of the limits of science itself.

Objectivity and Skills

"One of the most belittling experiences is to deride the 'black art' of a craftsman who gets consistent results by a certain ritual which he cannot explain and then to discover that his actions in fact held a deeper technical significance than we understood at that time from our simplified model." - Richard Heyser

Central to "The Great Debate" is the question of science's capacity for encompassing within its domain all forms of knowing. The objectivist position appears to be that understanding reality is a formalized process, which, if its rules are correctly followed, will establish an unambiguous, universal truth. Adherence to the prescribed methods is the only way of revealing nature's secrets. This belief is reflected in the blind testing methodology, detailed later in this paper. So great is the objectivists' faith in blind testing (and the underlying formalized method on which it is based) that they refuse to listen for themselves[4]. (11) This reflects a general belief that no forms of knowing exist outside those revealed through the prescribed rules of scientific method.

I propose that other kinds of knowing are possible. Many skills, including critical listening, cannot be objectively quantified; some forms of knowledge are tacit, unspecifiable, and inarticulate. (12) The scientific dogma to which the audio engineering establishment adheres tends to reject as unreal any phenomenon that cannot be measured or quantified.

Polanyi offers two examples of skills that fall outside the formalized domain of science:

"It follows that an art which has fallen into disuse for the period of a generation is altogether lost. There are hundreds of examples of this to which the process of mechanization is continuously adding new ones. These losses are usually irretrievable. It is pathetic to watch the endless efforts - equipped with microscopy and chemistry, with mathematics and electronics - to reproduce a single violin of the kind the half-literate Stradivarius turned out as a matter of routine more than 200 years ago." (13)

More specifically, Polanyi objectively analyzes the very simple skill of bicycle riding, using the formalized prescriptive methods of scientific investigation:

"When he starts falling to the right he turns the handlebars to the right, so that the course of the bicycle is deflected along a curve towards the right. This results in a centrifugal force pushing the cyclist to the left and offsets the gravitational force dragging him down to the right. This maneuver presently throws the cyclist out of balance to the left, which he counteracts by turning the handlebars to the left; and so he continues to keep himself in balance by winding along a series of appropriate curvatures. A simple analysis shows that for a given angle of unbalance the curvature of each winding is inversely proportional to the square of the speed at which the bicycle is proceeding.

"But does this tell us how to ride a bicycle? No. You obviously cannot adjust the curvature of your bicycle's path in proportion to the ratio of your unbalance over the square of your speed; and if you could you would fall off the machine, for there are a number of other factors to be taken into account in practice which are left out of the formulation of this rule. Rules of art can be useful, but they do not determine the practice of an art; they are maxims, which can serve as a guide to an art only if they can be integrated into the practical knowledge of the art. They cannot replace this knowledge." (14)

Although the physics of riding a bicycle can be expressed and understood rationally, objectively, and unambiguously, another component is necessary to ride a bicycle - tacit knowledge. Without ever having ridden a bicycle, a person who demonstrated a knowledge of bicycle-riding physics would appear to know how to ride a bicycle. Conversely, the scientifically illiterate person, with absolutely no knowledge of Newtonian physics, could be a bicycling expert yet be unable to express this tacit knowledge. Without moving from the theoretical domain to the experiential domain, one would be tempted to believe that the person who could articulate the physics of bicycle riding could indeed ride a bicycle while the person who could not express his tacit, inarticulate knowledge, could not.

The example of bicycle riding demonstrates that knowledge gained by studying theory is very different from knowledge gained by experience and practice. Knowledge without experience is empty, devoid of the reality that theory represents. Indeed, science education emphasizes practical experience because there is no substitute for it:

"The large amount of time spent by students of chemistry, biology, and medicine in their practical courses shows how greatly these sciences rely on the transmission of skills and connoisseurship from master to apprentice." (15)

Clearly, there are forms of knowing outside the realm of formalized study. The objectivists' attempt to reduce the art of designing audio equipment - and the use of personal skills in evaluating the results - to a prescriptive method (as exemplified by blind-testing methodology discussed below) reflects an unawareness of the role inarticulate knowledge plays in all facets of human existence.

The objectivists' rejection of this form of knowing, coupled with faith in scientific method's infallibility and unlimited capacity to reveal nature's singular truths, is the very foundation of "The Great Debate."

Language

". . . the root cause of the continuing fight between subjective and objective audio . . . is not *that* either *is more correct than the other . . . rather it is due to the fact that they do not speak the same language."* - Richard Heyser

One of the foundations of the dichotomy between those who explore audio phenomena by listening and those who rely strictly on measurement is the disparity of language between the two schools of thought. To the objectivists, who believe every aspect of an audio component's sonic performance can be measured, quantified, and communicated unambiguously through mathematical symbols, the language used by critical listeners to describe a component's sound is nothing more than vague poetic nonsense. Examples of the critical listener's lexicon include the expressions "low-frequency extension," "air," and "bloom." I would like to examine these terms in the context of their relative abstraction or expressiveness.

Within these descriptions used by critical listeners, there is a great diversity of perceived meaning among those hearing these expressions. The meaning of the term "low-frequency extension," for example, is easily understood by virtually anyone who has listened to two different pairs of loudspeakers. The expression has meaning to a large segment of the population because it describes a phenomenon they have experienced directly for themselves.

The next term cited, "air," is meaningful to a smaller percentage of the population because it expresses an aspect of audio quality not consciously perceived by most casual listeners. It is abstract to those who haven't discerned this aspect of an audio system's performance.

Finally, "bloom" is even more unintelligible and abstract to most people because it describes a phenomenon not readily encountered, recognized, or discerned in an audio system. The ability of a playback system to reveal "bloom" is a subtle refinement rarely differentiated by the vast majority of the music-listening public. The word is absolutely meaningless to those who haven't experienced "bloom" in a music playback system, yet is highly descriptive and full of meaning to those who *have* experienced the phenomenon.

To those who associate audio equipment performance with technical terms and specifications rather than the listening experience, the lexicon of critical listening appears to be devoid of substance - worthless jargon designed to obfuscate rather than enlighten. Conversely, a musician with no technical knowledge of audio reproduction technology would find technical terms and specifications meaningless, bearing absolutely no relation to his reality.

Both the expressions of critical listeners and the measurement data generated by objective testing are symbolic representations of reality. Without direct contact with, and experience in, that reality, its associated lexicon is dismissed as unintelligible. Language must be used repeatedly, consistently, in context, and relate to matters of experience to acquire meaning.

The following passage illuminates the inextricable bond between language and understanding:

"An illustration - akin to that of topographic anatomy by which we exemplified the ineffable - may exhibit this dual movement of comprehension in learning a language. Think of a medical student attending a course in the X-ray diagnosis of pulmonary diseases. He watches in a darkened room

shadowy traces on a fluorescent screen placed against a patient's chest, and hears the radiologist commenting to his assistants in technical language, on the significant features of the shadows. At first, the student is completely puzzled. For he can see in the X-ray picture of a chest only the shadows of the heart and ribs, with a few spidery blotches between them. The experts seem to be romancing about figments of their imagination; he can see nothing that they are talking about. Then as he goes on listening for a few weeks, looking carefully at ever new pictures of different cases, a tentative understanding will dawn on him; he will gradually forget about the ribs and begin to see the lungs. And eventually, if he perseveres intelligently, a rich panorama of significant details will be revealed to him; of physiological variations and pathological changes, of scars, of chronic infections and signs of acute disease. He has entered a new world. He still sees only a fraction of what the experts can see, but the pictures are definitely making sense now and so do most of the comments made on them. He is about to grasp what he is being taught; it has clicked. Thus, at the moment when he has learned the language of pulmonary radiology, the student will also have learned to understand pulmonary radiograms. The two can only happen together. Both halves of the problem set to us by an unintelligible text, referring to an unintelligible subject, jointly guide our efforts to solve them, and they are solved eventually together by discovering a conception which comprises a joint understanding of both the words and the things." (16)

By confining one's experience exclusively to technical parameters and excluding listening to a component's musical performance, it becomes clear why audio objectivists dismiss as nonsense the language used to describe component differences: they have no experience to which it relates.

Scale

Another problem related to the language used to describe the sound of audio components is the matter of scale. Objectivists claim that perceived differences are magnified out of proportion by ulterior motives[5]. (17) I submit that this question of scale reflects varying sensitivity between different individuals when confronted by the same stimuli.

The ability of certain individuals to demonstrate apparently preternatural skills is well documented. These individuals have worked at developing a particular sense, either out of a survival need or merely by practicing it daily in their professions. Examples of these skills are described by Csikszentmihalyi:

"The flexibility of attentional structures is even more obvious when they are compared across cultural or occupational classes. Eskimo hunters are trained to discriminate between dozens of types of snow, and are always aware of the direction and speed of the wind. Traditional Melanesian sailors can be taken blindfolded to any point of the ocean within a radius of several hundred miles from their island home and, if allowed to float for a few minutes in the sea, are able to recognize the spot by the feel of the currents on their bodies. A musician structures her attention so as to focus on nuances of sound that ordinary people are not aware of, a stockbroker focuses on tiny changes in the market that others do not register, a good clinical diagnostician has an uncanny eye for symptoms - because they have trained their attention to process signals that would otherwise pass unnoticed." (18)

Similarly, the audio reviewer, whose chosen profession is discerning differences between audio components and who practices his skill daily, develops a sensitivity that appears farfetched to someone not similarly attuned[6]. The audible differences reported thus seem overstated to those who have not developed such an ability or who are unaware that such abilities can exist.

Responsible Reporting and Psuedoscience

Nothing irks the scientific audio community more than reading or hearing about some new audio device or technique that reportedly changes the laws of physics or claims to have discovered that existing laws are somehow suspended by the device or product. The world of high-end audio abounds in this type of nonsense. There will, however, always be a few individuals in any field (Velikovsky in astronomy, for example) who cross the line from rationality to nonsense.

Unfortunately, there has been an effort to discredit all subjective critical listening by attempting to link the entire high-end audio industry and responsible critical listeners to absurd pseudoscientific claims. This "guilt by association" technique is an affront to all serious listeners who repudiate the mumbo-jumbo and pseudoscientific elements of audio. The responsible high-end press, whose allegiance is to its readers, has a duty to expose such fraud for what it is, both in the interests of truth and to protect its readers from buying worthless devices[7,8].

There is a regrettable tendency for marketers of audio products to invent incredible explanations of why a particular device has an audible effect. The phenomenon may be very real, but is given a false interpretation by its discoverers. This false interpretation does not necessarily mean that the discovery is ineffectual; only that the explanation is false. The history of science is filled with examples of a real phenomenon being attributed to unlikely and unscientific causes, followed by a concerted attack - what Polanyi calls "destructive analysis" (19) - by the scientific community before the underlying causes are understood.

The case of hypnotism is illustrative. Franz Mesmer's dissertation at the University of Vienna in 1766 suggested that the gravitational attraction of the planets affected human health by affecting an invisible fluid found in the human body and throughout nature. This theory evolved into "animal magnetism," wherein the invisible fluid in the body acted according to the laws of magnetism. According to Mesmer, "animal magnetism" could be activated by any magnetic object and manipulated by a trained person. Mesmer was accused of fraud and fled to Paris where he enjoyed a lucrative practice, based on patient testimonials. A commission appointed by King Louis XVI to investigate Mesmer's methods reported that Mesmer was unable to substantiate his claims. (20)

Physician John Elliotson later expounded a whole system of laws governing animal magnetism. "He claimed that the magnetism of a glass of water could be graded by dipping one finger into it, or two fingers, or the whole hand. Another 'law' declared that mucous surfaces of the subject, like those of the tongue or eyeball, were capable of receiving a greater mesmeric stimulus than the skin. All this was nonsense and proved to be nonsense. And since the assumption had not yet dawned on anyone that hypnotic suggestion was the effective agent of Mesmerism, the conclusion seemed inevitable that Elliotson's subjects were impostors, who were either deluding him or colluding with him." (21) Elliotson appealed to his attackers to consider the practical evidence of his technique: "I have given the details of 76 painless operations. In the name of common sense and humanity, what more is wanted?" The fact remained that Elliotson's technique did indeed have a beneficial effect on his patients.

Polanyi interprets:

"Not until the concept of hypnosis was established as a framework for the facts could those facts be eventually admitted as true. Indeed, whenever truth and error are amalgamated in a coherent system of conception, the destructive analysis of the system can lead to correct conclusions only when supplemented by new discoveries. But there exists no rule for making fresh discoveries or inventing truer conceptions, and hence there can be no rule, either, for avoiding the uncertainty of destructive analysis." (22)

Similarly, today's false interpretations of audible phenomena are subject to the same form of destructive analysis as was applied to hypnotism. Because an effect has no rational explanation, it

doesn't automatically follow that the effect is nonexistent. Just as hypnotism was a very real effect - yet denounced as fraud - many audio devices produce a very real effect. They too, however, are denounced as fraud because the underlying causes are misrepresented: their behavior has not yet been explained by audio science.

To subjective critical listeners, the determination by which an effect is judged to be real or illusion is made in the listening room, not on the basis of its theoretical compatibility with established dogma. Many now-established phenomena in audio would never have been discovered had individuals not investigated them by critical listening. Rather than engage in destructive analysis, the scientific audio community should listen for itself and investigate these phenomena. The idea that nothing more remains to be learned about apparently simple systems (power amplifiers, for example) is ludicrous. Even more ludicrous is the belief that all aspects of the relatively new field of digital audio are fully understood by science. In fact, the effectiveness of some Compact Disc-related accessory products illustrates just how lacking our knowledge of digital audio really is. This isn't an insult to audio scientists; rather, it is a call to action to investigate these phenomena. It is ironic that the very individuals best suited to study these effects are the least likely to listen for themselves, and the most likely to dismiss such possibilities as pseudoscientific nonsense. Indeed, there sometimes seems to be an inverse relationship between an individual's scientific skills and his willingness to listen for himself.

Scientists should ignore claims that are patently absurd; there is only so much research time and money. Similarly, audio journalists should denounce false interpretations for what they are, and indeed many do. But the criterion by which a claim is prejudged patently absurd or a possibility worth investigating should be its audible effect - knowledge derived from firsthand listening - not its compliance with established theory.

The objectivists' "rejection without listening" doctrine is an impediment to the advancement of audio engineering.

The High-End Audio Industry: Fraud, Delusion, or Reality?

"An art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists." - Michael Polanyi, *Personal Knowledge*

If, as the objectivists claim, all competently designed and manufactured audio components are sonically identical, then it follows that the entire high-end audio industry is a fraud perpetrated on an unsuspecting public. This view would seem to suggest that the music-listening world needs nothing more than an inexpensive receiver - provided, of course, it had lots of features and the front-panel markings were easy to read. Indeed, one of the objectivists' objections to high-end audio are the often high prices of certain components. They believe the public is being systematically exploited, driven by a high-end audio "journalistic elite" who "irresponsibly" recommend components based on a sound quality no different from any cheap, competently designed product. (23)

To subscribe to this theory, one of two premises must also be accepted: 1) that the entire high-end audio industry realizes the components they design and build are no better than any others, and are thus engaged in premeditated collusion and fraud to perpetuate their own existence; or 2) that everyone associated with high-end audio lives in a fantasy world, victims of the same delusions that defraud consumers of their money. Maintaining that no sonic differences exist between competently designed and manufactured products forces one to embrace one of these two scenarios.

Let's take the first premise - that high-end audio companies willfully engage in fraud, knowing that their products sound no better than any others. If that were the case, why would so many of them spend large sums of money on sophisticated computer-assisted electronic design software and

hardware? On elaborate dedicated listening rooms? On expensive associated components with which to audition their own products? On continuing education for their designers? Why would they include expensive resistors and capacitors in their products - components sometimes embedded in potted modules never seen by the consumer? Even a cursory examination of this position reveals its absurdity. The second premise - that high-end product designers (and everyone else in the industry) are subject to mass delusion - is equally absurd. Many high-end audio component designers hold advanced engineering degrees and possess solid scientific backgrounds. Can it be believed that their entire careers and life's work - designing better-sounding equipment - are based on delusion and fantasy? That with every new circuit evaluation in the listening room the designers (and everyone else in the company who listens) consistently hear differences that don't exist? That the general acceptance of the audible superiority of certain capacitor types, passive components, wire, and layout techniques are figments of the collective imagination, perpetuated through the power of suggestion and dishonest journalists? That every consumer who chooses a component based on sound quality is similarly deluded?

I propose that it is more reasonable to believe that audible differences exist between, say, polystyrene and electrolytic capacitors or silver and copper wire, than either the mass-fraud or mass-delusion theories of high-end audio.

Blind Listening Tests

"In our description of nature the purpose is not to disclose the real essence of the phenomenon but only to track down, so far as it is possible, relations between the manifold aspects of our experience." - Niels Bohr, *Atomic Theory and the Description of Nature*, (1934)

At first glance, it would seem that proving or disproving the audibility of a certain phenomenon is a simple proposition: Expose a subject to the two stimuli in question, prevent the subject from knowing the identity of the stimuli, and instruct the subject to correctly identify a particular stimulus. If the subject identifies a particular stimulus with statistically significant reliability, the phenomenon can be considered audible. If the subject cannot identify the particular stimulus under these conditions - with statistical certainty - the phenomenon is considered nonexistent. To the objectivists, questions of a phenomenon's audibility begin and end with blind testing.

Blind testing is the cornerstone of the objectivist philosophy. So great is their faith in blind testing's infallibility that they refuse to participate in subjective critical listening themselves. I quote Professor Lipshitz:

". . . I would like to comment briefly on a frequently-heard but nonsensical request which the 'subjectivists' make of us 'objectivists' - namely that we undertake tests to substantiate their claims for the audibility of a certain effect. How can you expect someone who professes not to be able to hear something to demonstrate its audibility? The onus clearly falls on those who claim they <u>can</u> hear the difference to be willing to subject their claims to the harsh reality of a blind listening test. *Only by doing so* can the validity of some of these assertions be either proven or refuted, and in the process can the field of audio engineering truly be advanced." (latter emphasis added) (24)

Without firsthand personal knowledge if differences exist or not, the objectivists' entire belief structure rests solely on the validity of the blind methodology (*"Only by doing so . . ."*). The objectivists live and die by the blind test.

Clearly, the objectivists consider blind testing as the great exposer of critical listeners' fraud and delusion - the subjectivists' Achilles Heel. I propose, however, that the entire blind methodology is the *objectivists'* Achilles Heel, for it is the sole basis for their position. Any underlying weakness in the blind methodology severely undermines their entire philosophical foundation.

Before examining the flaws of blind testing, a review of how these tests are performed is illustrative. Blind listening tests are frequently conducted under the following conditions:

A) The experimenter's agenda is often to prove that no audible differences exist rather than to discover if differences do exist. (25)

B) There is an adversarial relationship between subject and experimenter, and the subject is aware that he will be exposed to ridicule if he "fails."

C) The playback system, music, room, and other conditions are all foreign to the subject.

D) The experimenter controls all aspects of the test, including the music used, playback level, how long the subject can hear each presentation, how many times the subject can hear each presentation, the rapidity of switching between presentations, and in which musical passage the switching occurs.

E) The experimenter controls the number of successive trials without regard for the subject's fatigue factor, increasing the number if a trend indicating reliable identification appears[9].

F) The number of successive trials is very high, in an attempt to get a greater statistical sample size.

Tests conducted in this manner have frequently shown that subjects are unable to identify differences previously heard under other conditions. One must ask, however, if the lack of discrimination ability under blind testing conditions indicates that the phenomenon doesn't actually exist, or if these testing procedures interject hidden variables that invalidate the test results[10].

The question is not a trivial one. If blind testing is inherently flawed as a method of revealing differences, the objectivists' position becomes untenable.

I submit that the methods employed in blind testing, and the conclusions drawn from them, reflect a fundamental misunderstanding of human musical perception. Blind testing is flawed on two levels: the mechanics of the process, and the philosophical underpinnings on which the technique is based.

Beginning first with the mechanical and procedural problems of blind testing, the process is a gross distortion of reality in that the conditions present during blind testing are the antithesis of the conditions present during normal music listening. An individual's sensitivity to subtle differences is diminished during the stress and artificial conditions inherent in blind testing. The interactions between the subject and the test introduce unknown and unquantified variables into the experiment. In a discipline that prides itself on knowing and controlling all the experimental variables, it is surprising that the myriad characteristics of human musical perception have been so studiously ignored.

Among these variables are an individual's ability to maintain sensory sensitivity in the face of excessive stimulation. Research indicates that the limits of consciousness are far lower than previously assumed - limits that are routinely exceeded during blind testing. Csikszentmihalyi writes:

"At this point in our scientific knowledge we are on the verge of being able to estimate how much information the central nervous system is capable of processing. It seems we can manage at most seven bits of information - such as differentiated sounds, or visual stimuli, or recognizable nuances of emotion or thought - at any one time, and that the shortest time it takes to discriminate between one set of bits and another is about 1/18 of a second. By using these figures one concludes that it is possible to process at most 126 bits of information per second, or 7560 per minute, or almost half a million per hour. It is out of this total that everything in our life must come - every thought, memory, feeling, or

hour. It is out of this total that everything in our life must come - every thought, memory, feeling, or action. It seems like a huge amount, but in reality it does not go that far.

"The limitation of consciousness is demonstrated by the fact that to understand what another person is saying we must process 40 bits of information per second. If we assume the upper limit of our capacity to be 126 bits per second, it follows that to understand what three people are saying simultaneously is theoretically possible, but *only by managing to keep out of consciousness every other thought or sensation. We couldn't, for instance, be aware of the speakers' expressions, nor could we wonder about why they are saying what they are saying, or notice what they are wearing.*

"Despite its great powers, attention cannot step beyond the limits already described. It cannot notice or hold in focus more information than can be processed simultaneously. Retrieving information from memory storage and bringing into the focus of awareness, comparing information, evaluating, deciding - all make demands on the mind's limited processing ability." (emphasis added) (26)

The rapid development of fatigue in blind listening test subjects due to the increased information processing was reinforced by research carried out at Denmark's Technical University in Lyngby. In a 1989 AES paper examining the development of listening test methodology for the European Eureka project, Soren Bech demonstrated that the number of tests listeners are asked to carry out had a strong negative effect on their ability to make consistent value judgments. (27)

The finite and limited reserve of concentration is depleted by the myriad unfavorable conditions inherent in blind testing cited above, leaving little left to discriminate subtleties, much less interpret the *meaning* of the music - a subject I shall discuss later.

This situation creates a paradox: the harder one tries to discern a difference, the more difficult it is to detect the difference. The allegation that differences detected under optimum conditions vanish under blind conditions because the phenomenon never existed in the first place should be reexamined with a new appreciation for the psychological variables imposed by the limitations of consciousness. Critical listeners thus reject blind listening tests not because they are *too* rigorous, but because they are *not rigorous enough.* They fail to take into account the relationship between the subject and the test conditions. Ideally, a test should be devised in which the subject is unaware an experiment is being conducted - a "triple-blind" test, if you will.

A common trick among recording engineers is to tell an anxiety-ridden vocalist about to lay down an overdub that the first run-through of the song is just to set levels and practice - the tape machine won't be running. Of course, the good engineer knows that this will often be the best performance the artist can give and pushes the "Record" button - to the subsequent relief and gratitude of the artist after realizing the subterfuge. Similarly, subjects undergoing listening tests should be oblivious to the fact that their performance is being monitored.

When blind listening tests, despite their effect of obscuring audible differences, indicate that an audible phenomenon does exist (a phenomenon denied by the engineering community), the results are either incorrectly reported as a null[11], or judged "not statistically significant." (28) The "disinterested" experimenter often chooses to believe that certain subjects enjoyed an amazing run of luck rather than that they could discriminate a difference the experimenter had previously concluded in his own mind to be inaudible. For example, during the power-amplifier listening tests conducted at the 85th AES Convention in Los Angeles, a prominent reviewer of high-end equipment - a trained, skilled listener - identified a particular power amplifier in five out of five double blind trials[12]. His performance was dismissed by the experimenter as that of a "lucky coin." The experimenter explained the use of this term to the subject: if one flips a coin enough times, five heads in a row will appear on occasion. (29)

I submit that it is a greater act of faith to believe that this trained critical listener was "lucky" than to even entertain the prospect that the listener could discriminate between the two power amplifiers.

When evidence supports a hypothesis in conflict with one's preconceived ideas, the true scientist will explore that hypothesis and develop further experiments to verify or refute that hypothesis, not cling tenaciously to prejudice.

Perhaps the strongest indictment of blind listening tests is, ironically, the very test cited by the objectivists that all power amplifiers sound alike. This test "revealed" that power amplifiers of widely varying designs and price were sonically identical. (30) Amplifiers as diverse as an output-transformerless tube design, an expensive solid-state unit, and a $220 Japanese receiver, were all judged - under blind conditions - to be sonically identical. These amplifiers were as different from each other - on an objective basis - as one could assemble. Despite the large measurable differences between these amplifiers, the listeners could not distinguish among them.

On one hand, the objectivists claim that blind testing is very sensitive and the only method available to verify audible differences between components. On the other hand, these same objectivists claim that differences reliably heard by subjective critical listeners are the result of nothing more than trivial factors such as a slight level difference, frequency-response difference, or other easily identifiable and measurable effects.

I quote Professor Lipshitz:

"Certainly blind testing shows up differences very sensitively. If one needs convincing of this all one needs to do is to ascertain how small a level difference or frequency response mismatch can be reliably detected under such conditions. One can hear differences on the order of 0.2dB over an octave or so of bandwidth. But, by the same token, this means that if one wishes to hear differences beyond such relatively trivial linear differences (that is, if one wishes to ascertain the presence of audible nonlinear distortions), these linear differences really must first be minimized. If this is not done, the comparison test cannot draw any conclusion beyond the fact that an audible difference existed whose cause could have been nothing more than a simple level or frequency response mismatch. Without further tests, nothing new has been learned." (31)

The objectivists can't have it both ways. If "blind testing shows up differences very sensitively," yet the same methodology led to the absurd conclusion that an output-transformerless tubed amplifier, a high-end solid state design, and a $220 Japanese receiver, all having very different objective performances (including different linear performances), were sonically identical, then the inescapable conclusion is that blind listening tests are fundamentally flawed. If blind testing is truly sensitive to revealing differences, why were such gross differences between amplifiers in the cited test not detected?

Going beyond the nuts and bolts of blind testing, the procedure is suspect in that the entire reason we listen to music is subverted. Music isn't merely an arbitrary collection of pitches of varying amplitude; it is filled with meaning, expression, and feeling. Indeed, there would be no rational reason for listening to music if it were merely an incomprehensible and meaningless assortment of sound. It is the expression of the artist or composer that compels us to listen. The expression inherent in music is what drives the entire audio software and hardware industries; why else would people spend billions of dollars per year on audio hardware and software?

It is this expression that some audio components convey better than others. This characteristic of some components is colloquially know as "playing the tune." A component may measure well by any objective and rational standard, but this is no indicator of its ability to express the music's meaning - to "play the tune." This view implies that quality in audio equipment is not strictly a function of the component itself, but is dependent on the listener's musical sensitivity to this quality. This sensitivity to musical differences between components is a result of *caring* about the music. This is why blind testing conditions obscure differences between components; the music's meaning has no significance. Just as music is not merely a collection of pitches at varying amplitudes, the interaction between a listener and music cannot be reduced to mere "subjects" and "stimuli." Some of the differences critical

listener and music cannot be reduced to mere "subjects" and "stimuli." Some of the differences critical listeners report between components exist in the immediate relationship between music and listener.

During blind testing, the subject's tendency is to focus on a specific aspect of the presentation to aid him in identifying a particular component. This natural tendency to "try hard" is a fatal mistake because it is diametrically opposed to normal music-listening practice. By concentrating on the specific, the subject misses the overall experience that is the true indicator of audio equipment quality. It is ironic that legal documents and government regulations, which are carefully designed to be specific and unambiguous, are often the most incomprehensible and devoid of meaning.

Polanyi addresses this question by identifying two types of awareness, the "subsidiary" and the "focal," exemplified by driving a nail with a hammer:

"When we use a hammer to drive a nail, we attend to both nail and hammer, *but in a different way*. We *watch* the effect of our strokes on the nail and try to wield the hammer so as to hit the nail most effectively. When we bring down the hammer we do not feel that its handle has struck our palm but that its head has struck the nail. Yet in a sense we are certainly alert to the feelings in our palm and the fingers that hold the hammer. They guide us in handling it effectively, and the degree of attention that was given to the nail is given to the same extent but in a different way to these feelings. The difference may be stated by saying that the latter are not, like the nail, objects of our attention, but instruments of it. They are not watched in themselves; we watch something else while keeping intensely aware of them. I have a *subsidiary awareness* of the feeling in the palm of my hand which is merged into my *focal awareness* of my driving in the nail.

"Subsidiary awareness and focal awareness are mutually exclusive. If a pianist shifts his attention from the piece he is playing to the observation of what he is doing with his fingers while playing it, he gets confused and may have to stop. This happens generally if we switch our focal attention to particulars of which we had been previously aware only in their subsidiary role.

"The kind of clumsiness which is due to the fact that focal attention is directed to the subsidiary elements of an action is commonly known as self-consciousness. A serious and sometimes incurable form of it is 'stage-fright,' which seems to consist in the anxious riveting of one's attention to the next word - or note or gesture - that one has to find or remember. This destroys one's sense of the context which alone can smoothly evoke the proper sequence of words, notes, or gestures. Stage fright is eliminated and fluency recovered if we succeed in casting our mind forward and let it operate with a clear view to the comprehensive activity in which we are primarily interested." (emphases in original) (32)

The mutually exclusive qualities of subsidiary awareness and focal awareness affirm the paradox cited above: the harder one tries to discern a difference between components, the harder that difference becomes to detect. This paradox is expressed in the Zen concept of "effortless effort." I contend that much of an audio component's quality is perceived in this subsidiary awareness, and that focal awareness precludes perception of the component's real quality - the ability to convey the music's meaning.

More recently, acknowledgement of the mutual exclusivity of subsidiary and focal awareness has been found in sports training:

"When (the peak experience) happens on the tennis court, we are concentrating without *trying* to concentrate. We feel spontaneous and alert. We have an inner assurance that we can do what needs to be done, without having to 'try hard.' We simply *know* the action will come, and when it does, we don't feel like taking credit; rather, we feel fortunate, 'graced.' These moments seem to occur most frequently when players are volleying back and forth at the net. Often the exchange of shots at such short quarters is so rapid that action faster than thought is required. These moments are exhilarating,

and the players are often amazed to find that they make perfect placements against shots they didn't even expect to reach. Moving more quickly than they thought they could, they have no time to plan; the perfect shot just comes. . . . Quieting the mind means less thinking, calculating, judging, worrying, fearing, hoping, trying, regretting, controlling, jittering, or distracting." (33) (emphases in original)

These very same ideas are expressed by the Zen master D.T. Suzuki in his forward to *Zen in the Art of Archery*:

"As soon as we reflect, deliberate, and conceptualize, the original unconsciousness is lost and a thought interferes. . . . The arrow is off the string but does not fly straight to the target, nor does the target stand where it is. Calculation, which is miscalculation, sets in . . .

"Man is a thinking reed, but his great works are done when he is not calculating and thinking. 'Childlikeness' has to be restored with long years of training in self-forgetfulness." (34)

The parallels between the scientific philosopher's "subsidiary awareness," the tennis pro's "not trying," and the Zen master's "self-forgetfulness" are striking. All three examples demonstrate that our relationship to the physical world, and our actions within it, are manifestly dependent on our state of mind. These independent observations affirm that an individual's attitude is a significant variable in his ability to perform certain tasks. Yet blind listening tests ignore these variables, their promoters clinging naively to the concept of "objectivity." Any experiment in which there are unknown and unquantified variables invalidates the entire procedure.

There is also objective evidence that blind listening tests interject the unquantified variable of human interaction. It is widely known that the perception of music takes place in the right half of the brain, analytical reasoning in the left half. This has been shown with Positron Emission Tomography (PET) scans, a medical technique used in studying biochemical processes of organs, particularly the brain. Music listening produces increased right-brain metabolism, analytical reason increases left-brain metabolism. Activity in both halves is seen in subjects with musical training who simultaneously experience and analyze the music. (35)

The mental activity that occurs in blind listening - comparing, judging, calculating, trying to retrieve a memory of the previous sound, focusing on the specific, anxiety, fear of failing and of being judged, thinking ahead to the outcome, thinking of the consequences of success or failure, and questioning one's hearing ability - are all left-brain functions. These mental activities leave little room for sensitivity to how well the component conveys the music's meaning and value, the true and most important indicator of audio-equipment quality.

Repudiating the roles that meaning, feelings, emotions, and value play in audio science reflects a basic and prevalent misconception about science itself. Scientific method seeks to divorce value and meaning from the experimental process in the belief that personal involvement interjects bias and leads to erroneous conclusions. I submit that an individual's personal involvement in subjective critical listening interjects far fewer variables than the unnatural conditions of blind testing. The idea that science is value-free and exists independently of the individual is a falsehood that has given rise to this entire debate.

In summary, blind listening tests are severely compromised - if not completely worthless - as a method of determining what differences exist between audio components, judging the efficacy of devices or techniques, or proving the audibility of a certain phenomenon.

Conclusion

"You out there. Golden Ears, the person who couldn't care less about present technical measurements but thinks of sound as a holistic experience. You're right, you know." - Richard Heyser

The polarization of the audio community over "The Great Debate" is in many ways a false dichotomy. The responsible subjective approach, which combines careful controls with technical understanding, is far more objective than the method's critics realize. Conversely, the prescribed, formalized techniques to understanding audio phenomena - exemplified both by the blind testing methodology and the different cocktails of two-dimensional measurements felt appropriate by each engineer - are revealed by closer analysis to have greater subjectivity than their proponents would like to admit. Efforts to resolve "The Great Debate" must include an exploration of the conflict's underlying causes; without understanding these philosophical underpinnings, diatribe replaces dialogue.

The fact that musically significant differences exist between audio components - differences that cannot be measured with existing technology - is accepted as a truism by hundreds of thousands of critical listeners, both consumer and professional. Indeed, I suspect that a vast majority of the AES membership who use their ears professionally accept this reality[13]. Yet this reality, affirmed by the world at large, is dismissed as "fantasy" by a minority of academicians isolated by theoretical dogma and a refusal to listen for themselves. Unfortunately, it is the very scientists who have the skills and knowledge to explore these phenomena who summarily reject the methods of subjective critical listening.

Audio objectivists regard subjective listeners as anti-science - advocates of mysticism over rational inquiry. This perception is utterly false and immensely damaging to the goal of improving music-recording and reproduction technology. Subjectivists don't see science as an intrusion on their reality, but rather as one of many tools for advancing the art of audio engineering. Technically-oriented subjectivists see no inherent conflict in their methods; the objectivists' quandary is a result of their mistaken belief that any acceptance of listening impressions to judge audio equipment quality is tantamount to a rejection of rationality itself[14].

In the final analysis, we both have the same goal. But what is that goal? To generate a better set of numbers that somehow indicate more "goodness"? Achieve lower distortion? Produce improved specifications in the laboratory?

No. Our common goal is this: When a faceless listener somewhere in the world sits down before his playback system with his favorite music, he experiences the greatest joy our technology can convey.

Can audio engineering have a higher purpose?

References

(1) S.P. Lipshitz, "The Great Debate - Some Reflections Ten Years Later," presented at the Audio Engineering Society 8th International Conference, "The Sound of Audio," May 1990.

(2) Comment of participant at AES 8th International Conference, "The Sound of Audio," May 1990

(3) Comment of participant at AES 8th International Conference, "The Sound of Audio," May 1990

(4) J. Bruck, open letter to all AES members.

(5) Ibid.

(6) F. E. Toole, "Listening Tests - Turning Opinion into Fact," J. Audio Eng. Soc., Vol.30 No.6, p.431 (June 1982).

(7) S.P. Lipshitz, op. cit.

(8) M. Colloms, "Working in the Front Line," *Stereophile*, Vol.14 No.1, p.10 (January 1991).

(9) S.P. Lipshitz, op. cit.

(10) M. Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy*, New York, Harper and Row (1958) (First published by The University of Chicago Press, 1958), p.55.

(11) S. P. Lipshitz, op. cit., p.7.

(12) M. Polanyi, op. cit., p.62.

(13) M. Polanyi, op. cit., p.53.

(14) M. Polanyi, op. cit., pp.49-50.

(15) M. Polanyi, op. cit., p.55.

(16) M. Polanyi, op. cit., p.101.

(17) S.P. Lipshitz, op. cit., p.1.

(18) M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*, Harper & Row (1990), p.33.

(19) M. Polanyi, op. cit., pp.50-52.

(20) *Encyclopedia Britannica*, 1989 edition, Vol.8, p.47.

(21) M. Polanyi, op. cit., pp.51-52.

(22) M. Polanyi, op. cit., p.52

(23) S. P. Lipshitz, op. cit., p.3.

(24) Ibid., p.7.

(25) R. Harley, "Industry Update," *Stereophile*, Vol.14 No.7, pp.41-42 (July 1991).

(26) M. Czikszentmihalyi, op. cit., pp.28-29, 31.

(27) S. Bech, "The Influence of Room Acoustics on Reproduced Sound, Part 1 - Selection and Training of Subjects for Listening Tests," AES Preprint 2837.

(28) R. Harley, op. cit.

(29) Ibid.

(30) I. Masters, "Do All Amplifiers Sound the Same?," *Stereo Review*, January 1987

(31) S. P. Lipshitz, op. cit., p.2.

(32) M. Polanyi, op. cit., pp.55-56.

(33) W. T. Gallwey, *The Inner Game of Tennis*, Bantam (1974), pp.22-23.

(34) Ibid, p.21.

(35) A. Stiller, "Toward a Biology of Music," *The Audio Amateur*, One/1990, p.40.

Footnotes

1. A good example of this is the SOTA Panorama loudspeaker, reviewed by T. J. Norton in *Stereophile* (Vol.13 No.7, July 1990), Robert E. Greene and John Nork in *The Absolute Sound* (Issue 67, September/October 1990) and Art Dudley in *Sounds Like...* (Issue #8, Summer 1990).

2. It is sad but perhaps not uncoincidental that one of the oldest "objectivist" magazines was recently closed. No matter what reasons are formally given for a magazine losing circulation and eventually ceasing publication, the underlying reason is always that what it said did not correlate with its readers' own experiences.

3. In a talk given to the London section of the AES in 1985, the late Richard Heyser discussed this very subject, stating that while the reproduction and appreciation of music is a multidimensional experience, all that can be measured to assess quality are arbitrarily chosen two-dimensional plots showing how one parameter out of the multitude varies against another. His implication was that the subjective whole is more than the sum of these individual objective parts.

4. My colleague John Atkinson, during an argument a decade or so ago with a well-known English objectivist who insisted that all amplifiers sounded the same unless driven into clipping, finally gave in to frustration and asked just how many amplifiers had this man listened to to be so sure of his position. "One," came the reply, "That's all I *need* to listen to."

5. S. P. Lipshitz, op. cit.
"Many reviewers have, over the intervening years, dabbled with controlled tests and found that many imagined audible differences seem to vanish under blind conditions. This doesn't surprise anyone who has spent some time trying to get to the bottom of such cases, but does tend to make one cynical about the likelihood of ever resolving the question in the public's mind. After all, the sale of magazines is probably boosted by the controversy, and the more differences between components that reviewers are able to 'perceive' (or imagine that they have perceived) the better it is for their egos and their publishers. In other words, there may be strong ulterior motives for not wishing to resolve the matter."

6. In the late '70s, an East-Coast drive-unit manufacturer routinely tested tweeters on the production line by ear. The operator was instructed to sweep a sinewave through the unit and reject those that were rough-sounding, assuming that the boundary of performance would be in the region of 1-2% THD, the accepted threshold levels for distortion imposed on a pure tone. Reportedly, however, they

had to remove one person from this task. After a couple of weeks on the line, she was rejecting tweeters that had just 0.2% THD, an inaudible level according to the literature!

7. J. Atkinson, response to letters, *Stereophile*, Vol.14 No.6, pp.29, 31 (June 1991). Refutation of technical claims explaining the effect of a certain product.

8. R. Harley, "Compact Disc: Jitter, Errors, and Magic," *Stereophile*, Vol.13 No.5, pp.70-91 (May 1990). Refutation of technical claims explaining the effect of certain products.

9. S. P. Lipshitz, op. cit.
"It is usually best, rather than conducting a preset number of trials, to monitor the statistics as the trials proceed, and to extend the number of trials if there appears to be a reasonable possibility that a subject is performing somewhat better than random."

10. J. Atkinson, footnote to VTL Compact 160 amplifier review, *Stereophile* Vol.14 No.8, p.148. Discussion of the fact that some published blind tests of power amplifiers failed to discriminate differences due to output impedance differences that later, more careful work suggests *should* have been audible.

11. T. Nousaine, "The Great Debate: Is Anyone Winning?," presented at the 8th Audio Engineering Society Conference, "The Sound of Audio," May 1990.
Mr. Nousaine incorrectly stated *Stereophile* magazine's blind power-amplifier listening tests were "falsely reported" as indicating statistical evidence that the subjects could distinguish between power amplifiers. For a more rigorous statistical analysis of the data and an accurate reporting of the results, the reader is referred to the analysis by Professor Herman Burstein in *Stereophile*, Vol.12 No.10 (October 1989), pp.33-41. Mr. Nousaine also ignored completely in his paper the positive results of a later blind test, performed by Banks and Krajicek at Pomona College using samples of the same two amplifiers and featuring an almost identical methodology. This later test demonstrated statistically significant blind identification of the two amplifiers and was reported in full in *Stereophile* (Vol.12 No.11, November 1989).

12. J. Atkinson, "Industry Update," *Stereophile* Vol.12 No.1, January 1989, p.65.

13. To judge by the show of hands at the workshop on listening tests at the 85th AES Convention, the majority of the AES members present did feel audible differences to exist between amplifiers.

14. The greatest expression of the reconciliation between two apparently disparate modes of thought is found in Robert M. Pirsig's *Zen and the Art of Motorcycle Maintenance* (William Morrow & Company). Its ideas are the foundation of this paper.

Notes

Csikszentmihalyi (17) includes the following references relating to the limits of consciousness:

"The first general statement about the number of bits that can be processed simultaneously was by Miller (1956). Orme (1969), on the basis of von Uexkull's (1957) calculations, has figured that 1/18th of a second is the threshold of discrimination. Cognitive scientists who have treated the limitations of attention include Simon (1969, 1978), Kahneman (1973), Hasher & Zacks (1979), Eysenck (1982), and Hoffman, Nelson, & Houck (1983). Attentional demands made by cognitive processes are discussed by Neisser (1967, 1976), Treisman & Gelade (1980), and Treisman & Schmidt (1982). The attentional requirements of storing and recalling information from memory have been dealt with by Atkinson & Shiffrin (1968) and Hasher & Zacks (1979). But the importance of attention and its limitations was already known to William James (1890)."

All the Richard Heyser quotes are taken from *Time Delay Spectrometry*, a collection of his published papers, available from the Audio Engineering Society.

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About the Author

Robert Harley is Consulting Technical Editor at *Stereophile* Magazine, America's oldest and largest subjective-review magazine. He holds a degree in recording engineering, and has taught a college degree program in that field. Before joining *Stereophile* in 1989, Mr. Harley was a recording studio owner, recording engineer, technical writer, and CD mastering engineer. He has co-authored two previous AES papers, "Compact Disc Video (CDV) Signal Optimization" (presented at the 83rd Convention) and "Recording, Editing, and CD Mastering Entirely in the DAT Format" (presented at the 86th Convention), as well as writing two chapters on CD-ROM mastering for the McGraw-Hill *CD-ROM Handbook*. Mr. Harley is a member of the AES.

This paper is dedicated to Robert M. Pirsig.