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Beyond Measurements:
A Multi-disciplinary Framework for Aural Experience of Ancient Spaces

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Abstract

Acoustic measurements of historic spaces may have meaning. To ascertain the implications of these measurements, we must look to the social structure and cultural values of the original society, and apply what we know about human brain functioning. We attempt a form of triangulation by drawing on such supplemental information as first-person historic experiential narratives, observed cultural and personal behaviors, discovered cultural artifacts, and imaging scans of brain activity. The resulting multi-dimensional analysis will produce a complex set of insights. By identifying the patterns that appear within these insights, we can draw some plausible conclusions about the acoustic experiences of the original historic users, and speculate about the intentionality of those who created these acoustic spaces.

1. Which Measurements are Significant

It is often said that if you can't measure it, it isn't important. Many scientists will assert that if you cannot put the information into a set of numbers, and use them in equations, algorithms, and models, you don't know anything important. Since the Renaissance, we have built logical science based on replicable and reliable data; intuitive belief systems based on faith were not science.

However, significant thinkers in the last century have warned that by basing all our scientific work on hard numbers, we might be missing the main point of knowing. A sign in Albert Einstein's office is reputed to have read: "Not everything that counts can be counted, and not everything that can be counted counts." The anthropologist, Gregory Bateson, in his seminal work: Steps To An Ecology of Mind (1972) urged us to consider which differences are relevant. Bateson suggested that we must consult the workings of our minds and the systems in which our minds are imbedded in order to interpret significant information. Even the hard sciences are based on mental activities.

1.1 Important Questions, Illuminating Answers

This dialog between physicist and anthropologist leads us to realize that understanding cannot begin with answers. We must instead focus on questions. Answers in the form of facts and data -- numerical measurements -- are easily come by. The harder task is to determine the significant questions. Once we have determined our questions, we must then decide how we will create answers, which depend on both data and assumptions.

We begin our exploration of the sonic experience of space by asking the following questions: How did those spaces that produce certain auditory experiences come about? Did these spaces have designers with original intention to produce such experiences? Was it possible to produce certain spatial auditory experiences without any prior models? What, in fact, did the original users of these spaces hear? What did the original users hear that was important to them, and in what ways were these sounds important? How do we know that our answers today reflect what the original users of the spaces heard, experienced, and valued?

1.2 Hard Science Plus Soft Science

We often bifurcate the sciences into two types: hard and soft. Hard science data is achieved through careful measurement, based on a set of assumptions. To the degree that these assumptions hold true, the data accurately describes the phenomenon. Unfortunately, even in modern acoustics there are many cases where even the simplest measurements have fundamental flaws because the underlying assumptions are inaccurate. Consider the case of impulse response of a concert hall. Because the hall is a large enclosed space with thermal waves, one of the key assumptions underlying measurement of impulse response is violated: time invariance. The lack of time invariance undermines the validity of its measurement.

The soft sciences attempt to understand human beings as part of a dynamic society and a complex culture. They recognize that of the multiple variables which can alter the outcome of an experiment, many significant variables are unknowable, or at the least highly changeable. Instead of relying on a single point of information, a single type of measurement, social scientists look for patterns that repeat over time, and across many individuals and cultures. The strength of the discipline *aural architecture* is that it recognizes the significance of people in understanding sound in space. Measurements of physical sound, even if all assumptions hold true, do not present the whole picture because sound is human perception. In addition to describing the physical parameters of a sonic environment, we have to understand how people experience the sound in a space, and how they process and act on their experiences.

Individuals are not interchangeable, but they do behave in patterns, some of which are now understood. A plausible explanation that adequately accounts for numerous unrelated cases in a variety of cultures over many centuries is more likely to be valid than an explanation that explains a single case. Such an explanation is based on physical measurements plus additional sources such as introspective written and verbal reports of actual users, observed cultural and personal behaviors, discovered cultural artifacts, and imaging scans of brain activity. By utilizing a variety of sources, we can achieve triangulation; this is much more compelling than a single source explanation. A single source is like a single point, around which we can pivot 360 degrees. With two points we can build a line, limiting our explanations to toggling between two directions. With three points we can construct a plane upon which a structure can be built. The three points required to construct our explanatory structure are measurement, people, and culture.

1.3 The Limits of Understanding Historic Usage of Sonic Space

Perception is always personal. While two people may readily affirm that the concert is loud, there is no way to know if they experience "loudness" in the same way. We can only observe a common language label for that experience. Individual perception is determined by many factors, including genetics and personal history. Some people can hear things others can't. Even through there are genetic differences among people, brain wiring is not static over an individual's lifetime, but rather changes over time. The human brain is highly plastic. The type of neural processing allocated to a given function depends on the degree to which that function has become important by use. The brain reallocates its limited resources based on need. We say "use it or loose it." A musician expending thousands of hours on ear training can instantly hear whether a singer is on pitch or not, whereas a mere amateur listener usually cannot. On the other hand, the amateur music listener might be a parent with several children. Such a person can instantly determine which of their children is crying, but all crying will sound the same to a stranger.

The meaning, relevance, and prominence of a particular sense also depend on culture. Attitudes towards sound vary across culture and century. Sensory anthropology is the study of the role that a given sensory system plays for that culture. For example, the West African ethnic group, the Hausa, have two senses: seeing for the purpose of avoiding walking into a tree (navigation) and everything else which they call *Experiencing Life,* which includes hearing, memory, emotion, etc. For a culture where hearing is critically important for survival, for example in a rain forest-based hunting culture, the auditory cortex becomes stronger and more adept at hearing significant sonic nuances that would not be perceived by a modern person in a big city. In the same way, a person living in a sonically congested city develops techniques for sorting and perceptually minimizing sounds that are personally insignificant, and paying attention to those that do affect them.

It is tempting for a contemporary researchers to state that if they can hear a sonic phenomenon in a particular historic space, it was experienced by the original users in the same way. This is not defensible. Human beings are not interchangeable generic units. Personal history allows us to rewire our brains so that we can learn to hear some things, and learn not to hear other things. Culture directs the development of our brain wiring so that individuals existing in different cultures hear and interpret the same sonic phenomena in different ways. Just because I can hear something in a given space does not tell me what historic users heard in this space. I am not the historic listener, and he is not me. Researchers cannot use themselves as subjects and project backwards in time to provide descriptions and explanations for original historic users of a space – the differences are simply too great.

1.4 Explanatory Narratives

One way in which we achieve understanding of complex experience is by developing a narrative. Narratives allow us to organize large quantities of experiences, data and unknowns into a compact comprehensive story that we can manage. For example, if I walk by a cave and hear sounds emanating from it, I might develop a narrative that there is a spirit living in that cave “talking” to me. Alternatively, I might develop the narrative that there is a set of physical configurations in the cave that modify sound and project it outwards. Both narratives are equally satisfying and equally compelling; both are “truthful”. Yet, each is completely different, one from the other.

The challenge in going back in time is to figure out what was the narrative developed by the original historic users. Unless they specifically tell us what their narrative was, the narrative that a researcher develops today may have absolutely no resemblance to the narrative that original historic users developed. Our need for a satisfying narrative should not blind us to the fact that we cannot project ourselves backwards in time. Our narrative describing and explaining an acoustic space is very satisfying for us, but it is not the “truth” for the historic user. We cannot decide that we know how a particular historic acoustic space was designed, used and experienced based on a contemporary narrative, no matter how satisfying it may be. Our ”truth” is not their truth.

1.5 How Our Brains Are Wired – Experiencing and Communicating

How can we find out what historic users actually heard and experienced in historic spaces? Can we use what they wrote about their experiences? These writings do give us some information, some clues to what historic users experienced. But they are not strongly definitive on their own. And of course, as we go further back in time, the existence of written material becomes more scarce.

The brain substrates that create experience and communication are different. These strata have weak connective wiring to each other; we have a very hard time expressing what we are hearing and what we feel about what we are hearing. Much of our brain activity is below consciousness; we cannot access directly much of what our brain is doing, probably because such access would use too much brain capacity and is not required for survival. In addition, much of our brain activity is not directly wired to our language centers. Thus, the best we can do is to communicate indirectly, using metaphors, symbols, allusions, shared experiences, images, artistic creations, and so forth. We think we understand these, but even our understanding is indistinct; the way we build our understanding differs from person to person, culture to culture, time period to time period. Even when we have written documents describing sonic experiences, they are indefinite and hard to understand.

1.6 How Our Brains Are Wired – Creating and Reproducing Sound

There are additional brain functions that are of interest to us in understanding how sonic spaces were created and experienced. Reproducing a spatial experience requires multiple independent activities: observing, analyzing, imagining, remembering and creating. These functions are quite different from each other, located in different brain strata, not particularly wired together, and they are all minimally wired to the communication function.

The process of observing is an internal response to something that originates in the external world; analyzing, imagining, remembering and creating are entirely internal mental processes. Because sound is evanescent, the internal processes are not well-tied to externalities. For example, even if we really like a particular acoustic effect, we have a very hard time remembering it exactly, thus we cannot analyze it effectively, nor can we recreate it easily. In addition, we cannot communicate what it was like except in general metaphors and analogies. We might say a theater has a “bright” sound. We don’t remember the sound precisely; we only recall that the experience was what we decided to label bright when we heard it. We cannot easily analyze which spatial configurations created a sound we cannot accurately remember or describe. Thus, creating a sound in a space from a purely internal imagined model is very difficult. The words “auralization” and “visualization” are not symmetric: the former referes to an external computer simulation while the later refers to an internal mental activity.

Physical acoustics is complex; imprecise internality of sound compounds the difficulties. Even gifted composers cannot immediately produce the sounds that are in their heads the first time. Mozart and Beethoven were unique geniuses, the exceptions that prove the rule. Composers can easily try different combinations over and over until they are satisfied. A builder trying to produce a particular set of acoustic experiences cannot try over and over until he is satisfied. It is too difficult to redesign a physical space. Therefore, it is likely that when we hear a particular acoustics, it was the result of accident, the outcome of a combination of choices made for other reasons. The first Gothic cathedral was not designed in order to produce a great deal of reverberation; this was the outcome of design and construction decisions made to satisfy other interests. Because we experience it today does not mean the reverberation was originally purposeful and intentional.

1.7 Acoustics as Accident

Once a culture decides they like the sonic effects of a space, they end up using it to further their cultural values. When they attempt to reproduce a particular sound or set of sonic effects in another place, they must do so by using multiple reiterative attempts, trial and error until they get it the way they want it to be. Even Wallace C. Sabine in designing Boston Symphony Hall, modeled after Leipzig's Gewandhaus and using what was at that time extremely sophisticated techniques, found it diffiuclt to achieve the goal of enlarging an existing space while preserve its aural attributes.

Given all these considerations, it is difficult to believe that historic designers of spaces originally intended to create the acoustics that we hear. We cannot state that a particular acoustic environment was initally created to match a set of sounds that the builder had in his mind at the time. Acoustic intentionality in an original design is thus highly unlikely.

Even when a culture liked what they accidently heard, to reproduce these effects must have been enormously difficult. Only with great difficulty can human beings remember, imagine and recreate specific acoustics over time and across space. Reproduction of these original serendipitous acoustics was hard and not always effective. For all the successes in historic acoustic spaces we experience today, there were many more failures that either didn’t last, or usage patterns were adjusted to accommodate failures or semi-failures. When reproduction did work it was probably, in part, due to a narrative that successfully explained and communicated what had been done originally. If we can recover or recreate this narrative, we can add it to other types of testimonials to help us understand how historic users created and experienced their sonic spaces.

2. Exploring the Creation and Replication of Desirable Acoustics

By taking examples from a wide variety of cultures over the millennia in a wide variety of situations, we can begin to see a coherent pattern: it was possible to create and then recreate certain desired sonic experiences using accident, trial and error, and responding to other needs than those of acoustics.

There is a long tradition of sonic invention by trial and error. This approach was especially prevalent among craftsmen who were seldom part of the educated and literary class. While the writings of some philosophers may have reflected a deeper understanding of the science of acoustics, there is no evidence that such insights were present in the class of craftsmen. By trial and error, it was possible to discover desirable sonic experiences; by craftsman-like testing, modification and further trial and error, it was possible to replicate a desired sonic experience.

2.1 Original Intentional Sonic Experience - Musical Instruments

In ancient China, stone slabs, bells and bronze drums were produced in great numbers, consistently providing listeners with the same sounds. It appears that craftsmen had techniques they could use to reproduce sounds once they were determined to be desirable. These techniques appear to have been based on rules that were developed without intellectual or scientific foundation; instead they were ad hoc, based on experience and handed down as craft. Drawing inferences from surviving research literature on the history of musical acoustics in ancient China suggests a craftsman-like working knowledge of how to construct these sonically pure resonances. For example, the painted decorations on the heads of Han-dynasty bronze drums in fact replicate the standing wave pattern made when the drums are struck. Dust or dirt thrown on these heads make visual the sonic resonances, and reproduce the painted designs; these apparently served as guides to the drum craftsmen. Such craftsmen need not understand acoustics. Symmetric visual patterns produce pure resonances.

Even though we can show that certain sounds were intentionally reproduced in ancient times with instruments, we cannot then extrapolate from this the ability to intentionally reproduce desired sounds in larger acoustic spaces. While we now know that both small-scale instruments and large-scale spaces are governed by the same laws of sound physics, older cultures (especially craftsmen) would not have known that. Moreover, small-scale instruments could be fine-tuned side-by-side; this is not possible with large-scale spaces. Even though the ancient Roman architect, Marcus Vitruvius, wrote about acoustics, there is no evidence to show who would have shared that knowledge.

2.2 The Accidental Acoustics of Ancient Theaters

In ancient Greece, the mild weather, rolling hills and social democracy motivated the creation of large outdoor amphitheaters. Performances took place only once or a few times, and the subject matter was important for communicating the social values of the community. For these reasons it was important to ensure the largest audience possible, with the greatest ability to successfully experience the performance. Amphitheater design could have been based on visual sight lines, which also supported good acoustics as a side affect. The sharper angle of rise placed more audience members closer to the stage; this helped both vision and hearing. No direct knowledge or appreciation of acoustics was required to produce the resulting good acoustics. Visual quality and aural quality are correlated, but we cannot state that aural quality was the desired or primary outcome of amphitheater design. Correlation is not causation.

Later adaptations in theater included the skene which produced sonic reflections, miniature megaphones in masks which amplified actors' voices, and changes in oratory style. These were small in scale; as with musical instruments they could be the result of trial and error, and their effectiveness could be tested and modified. Trial and error, testing and resultant modifications are problematic on the scale of constructing large spaces because of the effort and time required. It may take years to create a variant of an original, large-scale successful model.

2.3 Medieval Cathedral Acoustics as Useful Symbol

The history of cathedrals has a written literature and we can therefore make more inferences about how such acoustic spaces came about. The model began with open air basilicas in ancient Greece. Eventually side walls were added to separate the audience from external noise, less clement weather, and social distractions. Advances in technology eventually allowed stone to replace wood as a building material; wood was prone to burning and had limited capacity for size. Expansion of Christianity put pressure on Church institutions to create spaces that could handle large congregations. The growing power of the Church supported the desire to create large, impressive religious structures. The building of these cathedrals supported and was supported by the growing economic power of the guilds involved in the endeavor.

The cathedral spaces became "god's home". This experience was solidified for the users because of the cathedrals' unique visual and aural attributes. By accident it was discovered that large enclosed spaces made of stone with high vaulting ceilings happen to have long reverberation. The resulting emotional experience of the unique acoustics was recognized by the Church, and was supported and extended by a changed visual and oral liturgy.

We can see that the uniquely impressive, resonant acoustics of cathedrals was not an original goal. It was an outcome of other symbolic, political, economic and social goals. Once the reverberant sonic experience acquired symbolic meaning, it was judged potentially valuable in furthering these other goals. The religion adapted to high reverberance and low intelligibility by using liturgical repetition and slow chants. We can see that the acoustic process was cyclical; the sonic experience was discovered, valued and incorporated into the whole. Cathedral acoustics arose by accident from other social, religious, and technical advances and ultimately came to serve these social and cultural goals.

Cathedrals are one of the clearest illustrations of how multiple technical and socio-cultural influences, including trial-and-error and craftsman-like modifications, first produce and then expand particular acoustics. The high resonance of cathedral acoustics was not the goal; it was judged valuable after the fact and changes in socio/cultural activities were made to utilize it.

2.4 Adaptive Use of Acoustics

The acoustics of early English theaters, like that of cathedrals, has some written history that can be used to make inferences. The circular form of these early theaters was modeled after or perhaps even borrowed from an existing space: bearbaiting arenas, which were familiar loci of communal entertainment. The circular form was also convenient for ease of set-up/take-down and transportation for an itinerant theatrical tradition. When available, theatrical troupes also used inn courtyards. The sonic effect of this circular format, with its straight-rising galleries and wooden construction of limited size, was to make the physical setting appear as an extension of the voice. These performance spaces came to be identified with a unique acoustic signature.

Once the unique acoustics of this type of space became clear, the theater adapted to it. The spaces were not originally intended for the purpose of the theater, but once the acoustics became familiar and predictable, plays and performance styles were changed to integrate the sonic experience.

While today scientific analysis explains the acoustic effects of using aural mass and voice impact, at the time these were not specifically understood as such. They were discovered experientially, and integrated into the theatrical experience post facto. The circular shape, vertical rising galleries, small scale and wooden interiors became wedded to their contemporary theatrical forms through adaptation. These became a model for 17th century theater design because the physical and artistic forms were now blended. The physical forms were not intentionally created in order to produce certain theatrical outcomes; rather, the theatrical forms adapted to the acoustic space.

2.5 Intentionality of Acoustic Experience vs. Effective Adaptation of Experience

In Madrid, a sculpture by Eusebio Sempere consists of a visually arresting array of polished stainless-steel tubes that dramatically reflects sunlight as it turns. Sempere was a 20th century Spanish minimalist sculptor, not a musician. However, some years after the the sculpture was installed, the acoustic scientist Francisco Meseguer realized that the sculpture was functioning as a “sonic band gap structure.” As it turned, it effectively reinforcing some sound frequencies while attenuating others. Later, Meseguer and his colleagues constructed similar structures. By manipulating the diameter and spacing of rods and studying how they changed sound in an anechoic chamber, they found they could create sonic band gap structures where certain frequencies could be amplified and others blocked out. Mesequer and his colleagues were neither visual artists nor musicians; they were scientists using sophisticated research methods and measurements.

For years, they had been studying the way that electromagnetic energy is manipulated by crystals in smaller structures, and they recognized the parallel in Sempere’s sculpture. After the fact, these crystal physicists purposely created band gap structures for sound and for electromagnetic energy. In contrast, Sempere was neither a musician nor a scientist; he was not interested in or perhaps not even aware of the potential for his sculpture to produce a sonic band gap effect. He only inadvertently created a sonic sculpture; the sonic qualities of the sculpture were only discovered after the sculpture was finished.

Since Sempere didn’t specifically write or talk about the sonic qualities of his sculpture, a group of archeologists discovering the sonic properties of the sculpture in the 22nd century might well ascribe intentionality to Sempere. He didn’t specifically deny it at the time, so a later researcher can freely ascribe intentionality. This would be especially true if the sculpture had been labeled “sonic sculpture” or “multi-sensory sculpture” over the intervening 100 years. However, there is nothing to support this designation of intentionality to the sculptor in creating the art-work. Just because we now perceive a sonic quality does not mean Sempere intentionally created it.

It is not unusual to encounter researchers ascribing intentionality in the absence of any indications that a certain sonic experience was in fact intentionally created. Take, for example, the “chirping” staircases at the Mayan pyramid of Kukulkan at Chichen Itza in Mexico’s Yucatan region. People standing at the base of these staircases and clapping their hands can produce a “chirping” sound, supposedly mimicking the sound of the quetzal, a mythic sacred bird. The chirping sound results from stone stair treads that are spatially periodic. Because these treads are rather narrow with what appear to be unusually high risers, some researchers have determined that the Mayan people not only knew sophisticated acoustic physics, but intentionally used this information to build staircases that produced this specific sonic experience. There are multiple possible explanations that, as Occam’s Razor recommends, are simpler and thus more likely. For example, the Mayan were sophisticated astronomers; there are four staircases aligned with four directions, of a certain number of steps, so perhaps the whole arrangement was based on astronomical symbolism --- we have no way of knowing today.

Like Sempere’s sculpture, the sonic experience in historic sites is noted after the structure is in place. As with Sempere, we have no specific indication of intentionality from the original creator. As with Sempere’s sculpture, the original sonic properties could well have been both created and discovered by accident. Mayan builders and contemporary multi-sensory artists, lacking scientific know-how, could, once they determine that they wanted a certain sonic experience, by trial-and-error engage in a process whereby the sonic experience is replicated by replicating the physical arrangement. Origination by accident; discovery by accident; replication through trial-and-error; these are the most likely explanations. Replication is the most likely candidate for intentionality: “I want to eat a cake that taste just like the cakes that my mother made for me when I was a child.”

2.6 Replicating the Acoustic Experience, not the Space

In 1900, Boston Symphony Hall was officially inaugurated. It was the first space we know of in human history to be designed specifically using the physics of sound. Wallace C. Sabine, the developer of the modern science of acoustics, was a young physicist who, through careful research and measurements, developed an understanding of and prediction for how sound moved through space according to certain parameters, specifically reverberation time.

Boston Symphony Hall was based on the second Leipzig Gewandhaus (built in 1884), which was known for its fine acoustics, especially for the romantic music of its time. The Gewandhaus held an audience of just 1,560; Henry Lee Higginson, the businessman/philanthropist who founded the Boston Symphony Orchestra, wanted the Boston version to be enlarged to accommodate 2,500 people. The famous architecture firm of McKin, Mead and White thought they could simply scale up the Gewandhaus layout by 30% in each of its linear dimensions. But Higginson had the wisdom and good fortune to hire a young Harvard acoustics expert to consult on the project. Sabine argued that scaling up the Gewandhaus' linear dimensions by 30% would create a space whose acoustical properties would be subpar. Architectural scaling was not a good choice for acoustic replication.

Sabine was the first person to use science to replicate acoustic parameters. He was the first to build spaces that replicated acoustic experience; he did not replicate the physical space. Boston Symphony Hall represents the invention of designing and building a sonic environment through prediction based on science, rather than on trial-and-error or serendipity.

No prior example of this scientifically-based attempt to reproduce the acoustic experience itself has yet been discovered. It is highly unlikely that an ancient or pre-scientific revolution culture could have successfully replicated a particular acoustic experience without also replicating the actual space, because a detailed knowledge of physical acoustics would have been required. Boston Symphony Hall, today considered one of the ten finest concert halls in the world, appears to be the first example of a particular desired sonic experience being specifically achieved by design based on acoustic principles, rather than by spatial replication.

Curiously enough, even though Sabine created a spatial design that produced an acoustic experience by using scientific principles, one-hundred years later those responsible for replacing the floor of Boston Symphony Hall did not have his confidence in science. Even with the highly sophisticated measuring tools, the amount of information we now have about acoustics, the hundred-years of experience building concert halls, they refused to allow science to replicate the old floor by predicting the acoustic properties of the replacement. Instead, the did it all the old way.

Enlisting highly specialized wood scientists and acousticians, the project began with the meticulous disassembly of the existing structure to ensure that the replacement floor would be installed in the same exacting detail. Exhaustive research was conducted on a host of issues including special protocols, materials and historical construction techniques from 100 years ago. Details of the project approach required an in-depth understanding of wood characteristics such as humidification tendencies, vibration induction dimensions, and the dynamic stiffness of the floor system (also known as resonance). They took a craftsman-like approach and exactly replicated the physical space, rather than replicating the acoustic experience.

3. The Impetus towards Replication

We have suggested that sonically pleasing historic spaces were most likely originally discovered by fortunate accident, rather than having been consciously and skillfully created. Furthermore, once a pleasing sonic experience was incorporated into a culture, further spaces producing similar sonic experiences were produced by replication.

There are several reasons to support such a conclusion, found by looking at human brain wiring, the working out of culture, and the nature of society. While the human brain is highly plastic, nevertheless we also require the comfort and predictability of familiarity. Thus, change is often interpreted as bad. As individuals and as a community we like what we know and dislike something new and thus different so strongly that we go to great effort to maintain what we know. Hence, even though replication of sonically pleasing spaces requires a great deal of energy, nevertheless throughout time we have done so over and over again.

3.1 Change is often Experienced as Bad

Even if Sabine had perfectly replicated the acoustics of the Lepzig Gewandhaus in Boston Symphony Hall, that new space would have had a different sound than the Boston Music Hall that it replaced. In fact, despite its preeminence today among concert halls worldwide, Boston Symphony hall was criticized when it opened. For the first few years after its inaugural opening, critics, listeners, and musicians kept up a steady stream of criticism of the new concert hall. They were comparing the aural personality of the new Boston Symphony Hall with that of the old Boston Music Hall. The new space did not sound like the old space; that was never the goal. The new aural personality was simply unfamiliar to those who had spent years listening to performances in the old hall.

Hostility toward the new space, followed shortly with ambivalence, should have been expected because any new art requires time and experience for resetting sensory and artistic expectations. Listeners often interpret change as a deficiency. Change is experienced as bad without reference to any stable internal criteria. We don't have a good memory of the details of a sound. We do remember comfort, familiarity, and predictability with a space's old aural personality. A new aural personality is discomforting in its unfamiliarity and lack of predictability. For good or bad, we want the old space and the old feelings back.

Quality is usually based on familiarity, rather than on any objective qualities. Human beings are not scientific measuring tools; we like what we know and dislike what we don't know. If a sensory experience is familiar, we decide it is good quality. If it is unfamiliar, we decide it is bad quality. Newness is strange and thus has too much challenge in it to be immediately labeled as good quality and thus desirable.

Art derived from a new set of rules is, by definition, unfamiliar. As Nicolas Slonimsky pointed out in his book: *Lexicon of Musical Invective; Critical Assaults on Composers Since Beethoven's Time* (1965) "music is an art in progress, and…objections leveled at every musical innovator are all derived from the same psychological inhibition, which may be described as Non-Acceptance of the Unfamiliar." Quotes from critics that he presents in his work to prove his point include:

- Wagner's *Lohengrin* was described as having "no more real pretension to be called music than the jangling and clashing of gongs…"
- Stravinsky's *Le Sacre du Printemps* was called the Massacre du Printemps.
- Gershwin's *An American in Paris* was "nauseous claptrap, so dull, patchy, thin, vulgar, long-winded and inane."
- Saint-Saëns's *Danse Macabre* was heard as the "clatter of the bones of a skeleton."

New sounds are usually rejected when first introduced. Hence cultures spend a great deal of energy replicating what is old, familiar, comforting, and predictable.

3.2 Integration of New Sound into the Culture

The aural experience of a space changes over time. The soundscape (or eventscape as we call it) is different today from what was heard 150 years ago. What we listen to and how we listen has changed; with the globalization of sonic electronic technology and a vastly increased population, the rate of these changes has rapidly increased.

Throughout history, great art that deviates from accepted forms has taken years to become appreciated and admired. Appreciation of novelty for its own sake, as in the post-modern artistic narrative, is a relatively recent phenomonen. If Wagner, Stravinsky, Gershwin and Saint-Saens had presented their work today, our post-modern narrative would have rescued these works from being dismissed with such emotionally laden criticism. Instead they would have been welcomed as innovative and creative.

The same principle can be applied to spatial acoustics. Traditionally, a completely innovative spatial sonic experience was at first derided because it was new. To be accepted required years of acclimatization. This process of gradual acceptance is speeded up if a cultural leader expresses an interpretation that favors the new. If the narrative embraces the new, the society will follow. If a famous architect tells us that his new concert hall has excellent acoustics, even if that is not measurably true, we believe him. As musicians, composers and conductors begin to adapt to the new spatial sonic realities, it becomes more a part of mainstream culture.

We have seen that sounds can evoke emotions and in this way become symbolically meaningful. When a powerful cultural sub-group can take over these sounds and use them for their own benefit, the larger society will accept the new sounds and their symbolic meanings. Today we expect movies, rock concerts, television, popular music and computer games to all be electronically modified. It is so common in recording that we don't even hear the difference when electronic modification is used. Our sonic experiences have been taken over and now symbolize our electronic times. Traditional, "acoustic" sound is now rare and specialized. The experience of sound depends on the culture's attitudes.

4. Summary

Epistemology: is the branch of philosophy concerned with the nature, scope, and limitations of knowledge. This field focuses on analyzing the nature of knowledge and how it relates to truth, belief, and justification. It includes a paradigm for producing knowledge, as well as skepticism about different knowledge claims. "How do you know what you know?"

"Plausible" and "consistent with" are very weak assertions, but strong assertions may not be possible for many types of questions.

4.1 Post-hoc Analysis

Post-hoc analysis, in the context of design and analysis of experiments, refers to looking at the data — after the experiment has concluded — for patterns that were not specified a priori. It is sometimes called by critics **data dredging** to evoke the sense that the more one looks the more likely some pattern will be found. More subtly, each time a pattern in the data is considered, a statistical test is effectively performed.

Post hoc pattern discovery is the weakest form of assertion. Much of the science of evolution and acoustic archaeology is post hoc pattern identification. Even if there is no alternative approach, post hoc conclusions are by their nature weak.

4.2 The Compelling Nature of Patterns

The human brain needs to find patterns even when none exist. This is true for intellectuals and philosophers, as well as the average person. Religion has been described as man's need to explain the unexplainable. If I were to throw a collection of coins on the table, we would immediately look for the pattern. That pattern we find can be so compelling that we could convince ourselves the pattern was the result of intention, forgetting its random origin. When looking at spatial sonic qualities and experiences, we must defend against becoming convinced that the random is actually intentional because the pattern is so compelling.

Instead, we must be willing to entertain the possibility of many different explanations being accurate in explaining what we hear. We must use discipline and structure to sort among them. Speculations vary in their likelihood of being true, and the best way to determine which of the speculations are strongest is to have multiple data points that support each other and point in the same direction.

4.3 Speculative Framework

Here is our personal view of the factors that influenced the way that historic acoustic spaces came about. This framework is consistent with a large amount of data from numerous unrelated fields, cultures, situations, and time periods. Hence, it has more power than a model built by analyzing a single case. Of the thousands of plausible explanation for the origin of a novel spaces, we consider our explanations to be the most likely. Ideally, a speculative explanation should incorporate all of the following seven factors.

4.3.1 Social Needs Determines Size of Audience

Size is everything. Being able to see and hear other members of the community is important for social cohesion, which is the driving force in determining the desired size of a space. A restricted elite needs a small space, an expanding audience needs a large space. The size of the social group and the size of the space are linked.

4.3.2 Building Technology Limits Size & Geometry

The nature of a space, its structural properties, and is geometry are determined by the available technology regardless of the social value system. Technological changes bias the kind of spaces that can be invented and then replicated.

4.3.3 Once Constructed, Listeners Adapt to Space

Once constructed, a novel space allows listeners within the culture to adapt to its visual and aural properties. Narratives are developed; cultural activities are modified; social, economic and symbolic meanings are then (post facto) connected to the novel space.

4.3.4 Experience Enhances Subjective Quality

We are creatures of habit; we are comforted by what we know. Quality often equals familiarity. We do not function like scientific measuring tools; we are subjective in our assessment of quality. Familiarity is know to be a major component of quality.

4.3.5 Future Spaces Replicate Earlier Spaces

After a novel space has been extensively used, familiar enhances the sense of quality and desireability. Replicatation preserves that familiarity because other spaces produce a similar aural experience as the original. Historically, replication was limited to duplicating the space itself because its aural properties could not be separated ftom the physical construction and geometry.

4.3.6 Incremental Evolution by Trial and Error

The definition of desirable acoustics changes over time, and these changes are usually incremental. Because of the complexity and expense of large spaces, they evolve by trial and error with corresponding sybolic shift. Scientific prediction of the aural attributes of a novel space only appeared in the late 20th century.

4.3.7 Symbolic Attachments to Spaces and/or Aural Attributes

Special symbolic meaning can become associated with either a particular space or its aural attributes, which are portable and replicatable. For example, local parisioners can see their cathdral as gods home, or they can experience enveloping reverberation as a replicated version of god’s home.