An Evaluation of The Relationship Between Social and Natural Phenomena in terms of Forming Knowledge in an Interdisciplinary Research Area: Architectural Acoustics

Dr. Onurcan Çakır
İzmir University of Economics – Department of Architecture, İzmir, Turkey
onurcancakir@gmail.com

ABSTRACT
Scientific knowledge in the field of acoustics includes both qualitative and quantitative data where objective measurement values and subjective quality ratings overlap and create a general understanding about the relationship between people and sounds. Architectural acoustics experts are expected to have knowledge about both sound theory and architectural design. In this paper, the history of architectural acoustics and the knowledge formation methods were evaluated in terms of philosophical approaches of contemporary philosophers like Robert Audi, Norman Blaikie, Martyn Hammersley and Karl Popper. In terms of philosophy of science, architectural acoustics has epistemologically an empiricist, ontologically a shallow realist stand point. It has a strict relationship with culture and limitations of human hearing. This field of research needs also to adopt subtle realist ontology in the studies. This paper also includes historical information about theoretical beginnings of architectural acoustics. Historical emergence of important scientific terms like reverberation time, normal loudness curves and subjective parameters for concert hall acoustics are discussed.

This paper covers epistemological and ontological approaches in architectural acoustics which are commonly used or neglected while forming knowledge. The practical use of acoustic knowledge and its relativity considering different case examples are discussed in the paper.
Keywords: Architectural Acoustics, Epistemology, Ontology, Philosophy of Science, Philosophy.

1. INTRODUCTION

Architectural acoustics is an interdisciplinary area of research where experts are expected to have knowledge about both sound theory and architectural design. These two different kinds of knowledge are built up with quantitative and qualitative data and come together for the acoustical comfort of people. Individuals stand on the middle point of architectural process where buildings are designed for people because they live or spend time in these constructions and their satisfaction is the key factor for the architectural evaluation. Room acoustics, noise control, speech intelligibility, impact and vibration insulation are the main concerns of architectural acoustics.

In all kinds of building technology science (BTS) topics like acoustics, lighting, heating, cooling and ventilating, there are certain assumptions concerning comfort issues which are derived from user attitudes in time. Some of these are directly connected with physical and objective values which can be calculated, where some give references to our feelings and cannot be defined under guidance of numbers. Still, they can be formulated according to the overall perspective of that research topic and summarized. Doing post-occupancy evaluations (POE) is a common method which is used in order to determine the user satisfaction of the built environment. The results of these surveys create a basis and a general understanding about the studied research topic and all the derived information is transformed into data as knowledge. This paper includes discussions about

acoustic epistemology, how acoustic knowledge has been formed until today and which philosophical stages it should pass to be accepted as knowledge.

2. HISTORY OF ACOUSTIC EPISTEMOLOGY IN TERMS OF HUMAN HEARING AND PERCEPTION

Considering architectural acoustics, origins of sound theory is based on the theory of fluids and scientists / researchers like Leonardo Da Vinci, Galileo Galilei, Marin Mersenne, Giovanni Battista Benedetti, Robert Hooke, Isaac Newton, Pierre Simon Laplace, Daniel Bernoulli, Leonhard Euler, J. L. Lagrange, Sophie Germain, John W. Strutt and Lord Rayleigh have direct and indirect contributions on the development of acoustic theories by systematic explanations until modern acoustics (Lindsay, 1966), (Long, 2014). Knowledge grows by combining new theories with the known ones where former knowledge builds up the base for new formulations.

Sensations of Tone in 1860, a book written by Hermann von Helmholtz, "established the field as a science where measurement, observation, and a mathematical approach could lead to significant progress (Long, 2014)." His work was followed by John W. Strutt and Lord Rayleigh's *Theory of Sound* in 1877, where "such a clear presentation of acoustical phenomena was written before careful experimental work was possible (Long, 2014)." This statement leads us to consider about *deductive* research strategies, where producing the theory comes earlier than making experiments and observations (Blaikie, 2007). But in general, it can be stated that after modern inventions which enabled applying precise measuring techniques, architectural acoustics became a field of research where mainly *inductive* methods with *positivistic* approaches are used. To have a certain base for the measurements, there are standards for each type of measurement work. Epistemologically an *empiricist* and ontologically a *shallow realist* stand point is the general position of architectural acoustics as science, considering measurements and calculations which mainly constitute the quantitative part of this science. Nevertheless, taking subjective acoustic parameters in consideration, it can be argued that this field of research needs also to adopt *subtle realist* ontology in the studies. In architectural acoustics, generally certain acoustic parameter ranges are tried to be defined for people as optimum, which is actually a method to be questioned and discussed. Hammersley's definition of subtle realist ontology could be offered for qualitative architectural acoustics' approach to knowledge, as human behavior cannot always be limited and generalized taking only the majority into consideration.

> "This subtle realism retains from naïve realism the idea that research investigates independent, knowable phenomena. But it breaks with it in denying that we have direct access to those phenomena, in accepting that we must always rely on cultural assumptions, and in denying that our aim is to reproduce social phenomena in some way that is uniquely appropriate to them" (Hammersley, 1992).

Theoretical beginnings of architectural acoustics were started by W. C. Sabine in the late nineteenth and early twentieth centuries (Long, 2014). Sabine made the definition for the term 'reverberation time' (RT), an objective numeric value that can be calculated and measured, which makes this value a reliable base in order to compare two different rooms' acoustic settings. "RT is defined as the time it takes for the sound level in the room to decrease by 60 dB after a continuous sound source has been shut off" (Rossing, 2007). This value is there to create a worldwide accepted and understood standard. Without knowing what reverberation time defines, it would mean nothing saying that a room has the RT of one second. Quantitative scientific knowledge in a positivistic manner requires a standardized data processing where all these standards would create a base for the following inventions and formulations.

There are different calculation methods for this main acoustic concept. *Sabine, Norris-Eyring and Millington-Sette* methods are three main reverberation time calculation ways.

These empirical formulas are supposed to calculate similar values as results, but still, there are three options to find the RT of a room. Norris-Eyring equation is more accurate by calculating very absorptive rooms compared to Sabine method (Long, 2014). The reverberation time value in seconds is usually given with one digit after comma, because the calculation or the measurement of the second digit cannot be that accurate and the change in these digits would not be perceptible to people anymore. Limitations of human hearing define the studied range.

When it comes to judge the quality of a room, the RT value turns into a subjective value this time, where the optimum reverberation time differs between functions, music genres and even between people with different acoustic tastes. A common method is to generalize the preference of the majority as optimum and accept that taste range as standard. Figure 1 shows the suggested RT values for concert venues according to different music genres (Mehta et al., 1999). These are actually derived from old habits and experiences and it is also noted that these values are for people with 'normal' hearing. Stating a norm is seen as generalizing the taste or behavior of the majority. This is where we can see that architectural acoustics has presuppositions considering human hearing and all the statements are done according to them. Although it can be discussed whether the knowledge which comes from this kind of an ideology is scientific or not, due to practical reasons, majority is what science serves to and considering also other BTS topics, same situation is valid for all of them. As science is a way of making natural events understandable for human beings and as people are on the focus point of sciences' activities, subjectivity of even an objectively measured parameter is inevitable.

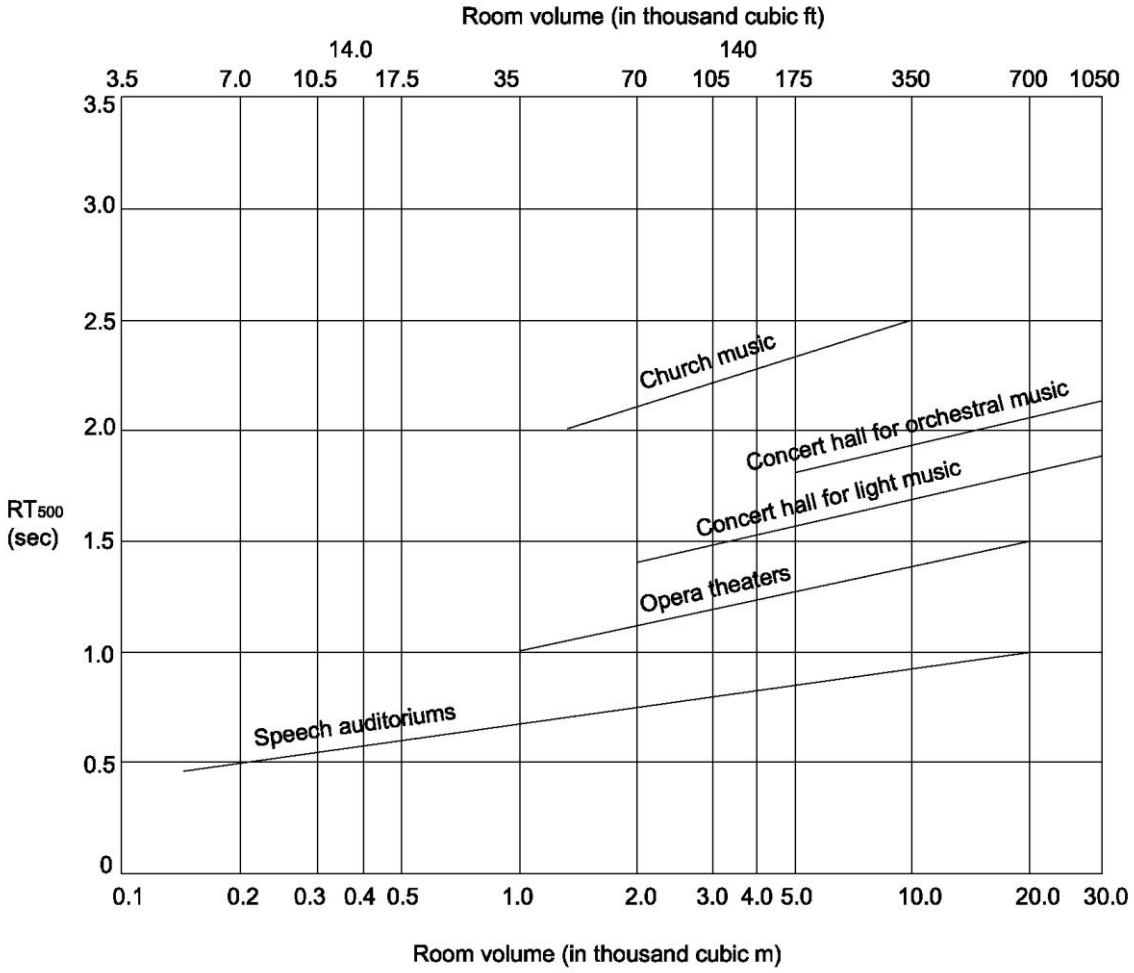

Figure 1: Preferred reverberation time values with the note that these suggestions are done for people with *normal* hearing (Mehta et al., 1999).

There are different approaches about calculation methods of sound phenomena. Simulations and calculations can be done with different techniques. The most commonly used method is to accept sound waves as rays and to use linear wave physics. The behavior of sound transferring particles introduces the finite element time-domain method, which is another way to explain the sound phenomena. There are alternative ways to simulate acoustic events, as there are a variety of theories, which aim to reach the same result. This indicates that even positivistic scientific knowledge may not be completely indisputable.

Creating new formulas by empirical methods is a way of making natural events predictable to people. Prediction and experience lead to understanding of physical actions which can be useful by making life easier for inhabitants. All the empirical methods are based on the assumption that there is a system of rules in the nature. Natural events are expected to occur in the same way as they did before. Actually, it is unpredictable at least for the mankind how the universe will behave after a moment from a *cautious realist* ontological point of view. "Even well-grounded beliefs can be mistaken (Audi, 2011)." The physics we know is only for the circumstances in that we live in. As a result of a change in a constant (e.g. gravity) due to any disorder in universe, all the formulas derived until now would be regarded as invalid. Physics try to define a system of rules, but the universe is built up and grows with chaos which creates an order as a temporary condition. Still, to have practical scientific knowledge which is useful for the time being, the physical events which are observable for people are formulized and transformed into data.

3. FORMING KNOWLEDGE BASED ON ACOUSTIC COMFORT

Considering concert hall acoustics, qualitative and quantitative methods come together for human comfort. In traditional concert venues, ornaments on the walls have an important place in terms of acoustics. They serve as diffusers so that the sound is distributed homogenously in the hall. As modern architecture is less ornamented, diffuser systems with modern materials are used now in contemporary concert halls in order to reach desired acoustic values. Architectural acoustics has a strict relationship with culture, where people's acoustic tastes are connected to the environment in which they grow up. Architectural trends affect acoustical parameters directly and as the music tastes are formed in centuries, standards are built up in the music genre's formation process; in other words, optimum values for acoustic parameters are defined taking familiar sound characteristics related to former experiences. This fact leads us to reconsider if knowledge is something transformable.

In 1962, Beranek proposed eighteen subjective parameters for concert hall acoustics considering human hearing and perception, such as brilliance, warmth, liveliness, ensemble and intimacy (Barron, 2010), (Beranek, 2004). Although the parameters defined by Beranek provide certainly a basis for concert hall acoustics, the criticism that these parameters are bound with context, taste and time, would be supported with the following statement:

> "Today, it is not certain that this particular list of terms would be the one used for characterizing a concert hall, but review of these attributes is useful and the reader is referred to Beranek's *Music, Acoustics and Architecture* (Beranek, 1962) as an important early influence on contemporary concert hall design" (Cavanaugh et al., 2010).

In order to reach perceptible information about physics, justification is a useful and instinctive method because of its conformity for human data processing and understanding during observing and analyzing natural events. This method has the uncertainty by stating after how many justified examinations the results are accepted as truth. Popper suggests the critical method for science, "the method of the search for and the elimination of errors in the service of truth (Popper, 1996)." Critical rationalism

combines deductive reasoning with falsification, but as this method requires a continuous process with unlimited falsifiable possibilities, it is hard to use falsification for practical scientific approaches. Using both justification and falsification for scientific approaches could help combining their strong parts and eliminating the weaknesses of each (Blaikie, 2007).

From a relativistic and partly skeptical point of view, we can say that it will be never possible to reach the absolute reality which is around us, where knowledge is justified true belief as stated by Audi (2011). Science is based on conjectural knowledge (Popper, 1996). Thus, our knowledge may be valid for a certain period of time. We can only record what has happened before and, based on that, guess what will be next. As we can never know the meaning and the aim of this universe's existence, we can actually never accurately guess what will happen after a moment. We live on the planet earth, which is a tiny little part of the continuously expanding space. Only if the process continues as it has done until now, we can find similarities and define 'rules' which can be called knowledge for us. The term 'knowledge' is a word created by and for human beings, like all the other words and languages. No creature except human beings is actually in search for knowledge, because the instincts of animals and the molecular chains of all materials are there for them to continue existing. Knowledge is a link between the universe and people, which is not helpful to reach the aim of the existence, but can be benefited from, in order to live more comfortably. This is what makes knowledge not divine but functional in a pragmatic manner in terms of science.

Our five senses are the main tools for us to catch data from the environment. Observation takes great place in positivistic sciences. The data we collect through our senses leads us to a knowledge, which is actually limited, at least limited with five senses. We are not able to discover if there is any other truth that could be observed with a sixth sense out of the boundaries which our bodies create. Even if a number of five senses were enough for observing anything in the universe, each sense is again limited in itself. For example, sound is a phenomenon with different perceptible frequency ranges for various kinds of animals and also human beings. The audible spectrum for people is generally accepted to be between 20 and 20000 Hz (Everest and Pohlmann, 2009). Sounds which are below the audible frequencies for human are called infrasound and the ones above it ultrasound (Rossing, 2007). We use ultrasound for medical and industrial purposes, where infrasound is especially created by natural events like earthquakes. In addition to this, dogs and other animals are able to perceive higher and lower frequencies. An animal doesn't search for knowledge; it has natural instincts for continuing its life. But a human being doesn't content himself / herself with the instincts and seeks after truth and knowledge. The only part of that truth, which s/he is able to find out, is again bound with the time, physical abilities and culture. "Human beings have an inner necessity to comprehend the world as a meaningful cosmos and to know what attitude to take before it (Weber, 1953)." We can say that searching for truth is also an instinct of human beings, which does not necessarily have to reach a certain result.

4. STANDARDS, THE "NORMAL" AND OBJECTIVITY

People have different limitations considering their five senses. Blind people can't perceive the world visually and the deaf people can't hear which actually doesn't change the truth 'out there' according to critical rationalist approaches. "[Critical rationalism] rejects sensory experience as a secure foundation for scientific theories, thus making 'pure' observation impossible (Blaikie, 2007)." Actually, in the same way, that there is the truth out there, doesn't change the realities which these people experience. While technology improves, ways to reach knowledge have to pass through these empirical stages in order to continue its journey to truth.

"*Loudness* is the human perception of the magnitude of a sound (Long, 2014)." There are frequency weighting schemes that can be considered as scales which enable to adapt measurable acoustic values to human perception (e.g. the A-weighted sound level dBA).

These are based on Normal Loudness Curves (Figure 2), which presume that people are less sensitive to low frequency sounds. Acoustical evaluations are done considering normal people's hearing and it can be inferred that that kind of knowledge is actually not the 'truth', but only some developed terminologies dependent on perception, which actually contradicts with positivism's main principles. In a hypersensitive or hearing-impaired case, or even for a normal person who is in a different psychological mode, all that knowledge would be invalid. The necessity of standardizing values for the majority of people overcomes objective facts which can be measured.

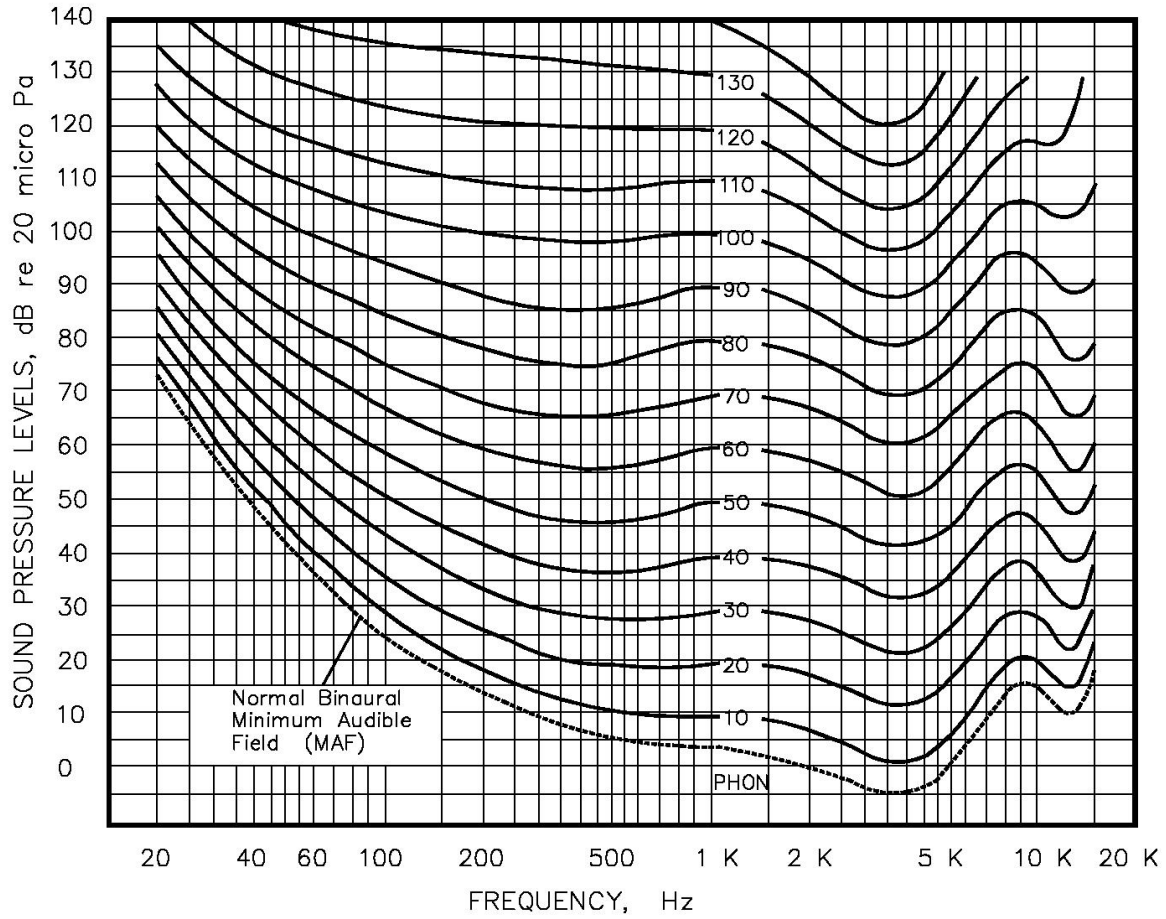

Figure 2: Normal Loudness Curves for pure tones from Robinson and Dadson's study in 1956 (Long, 2014), (Robinson and Dadson, 1956).

5. CONCLUSION

After industrial revolution and invention of electroacoustic systems (e.g. loudspeakers, microphones, telephones), the type of noise that the field architectural acoustics must handle has transformed. On the roads, car noise and especially in shopping malls and cafes, mechanical engine noises mixed with loud background music have become emerging problems which people have to face every day. "Critical Theorists regarded capitalist society as fundamentally irrational, in that it fails to satisfy existing wants and produces false wants and needs (Blaikie, 2007)." Technology has detrimental effects on human comfort besides its benefits. Scientific knowledge leads to new technological inventions, but we must be careful that these tools don't lower our physical comfort while enhancing some other conditions.

To conclude, architectural acoustics can be defined as a field which prepares scientific knowledge by measuring natural events, formulating calculation methods for acoustic phenomena and transforming these data into scales and ranges for people according to social facts. To provide acoustic comfort for people is the main purpose of this discipline;

thus, the perceptions, opinions, feelings and judgments of users form the general concepts of this topic. What we call knowledge in architectural acoustics, is actually formed of human reactions' generalizations and that knowledge leads us to standards which will either be accepted or transformed in time depending on changes in human perception due to living conditions of a certain period of time. Life in cities after industrial revolution created a new area of knowledge which is based on the properties of machines. There has been an issue called 'traffic noise' since cars with fuel burning motors were invented. After some years, if cars with electric motors become more common, this problem may disappear and the knowledge we have concerning traffic noise may be unnecessary for the next time period. Still, there will always be emerging issues for architectural acoustics to be dealt with, as long as human beings occupy spaces.

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