

## EPISTEMOLOGICAL MODELS IN PSYCHOACOUSTICS: A HISTORICAL OVERVIEW

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### Abstract

*Since Fechner set the basis for psychophysics, psychology of sound and musical perception started its course as a scientific discipline. During less than two centuries of history, anyway, it passed through many different epistemological paradigms, influenced by the changes occurred into the historical and philosophical panorama. Starting from Fechner's 1860 volume *Elemente der Psychophysik*, we explore these paradigm shifts, tracking some of the principal steps made by psychology of sound and music in its attempts to offer a model for discovering and explaining the scientific phenomena and laws underlying acoustic sensations and perception, “in tune” with the different theoretical frames of the most influential psychological theories of the XIX<sup>th</sup> and XX<sup>th</sup> century.*

As we just entered through the doors of the new millennium, psychophysics still keeps a prominent position amongst the many disciplines living inside the widest field of psychological researches. In parallel, psychoacoustics represents maybe the most dynamic part of the experimental psychology of music, and it gained vitality especially with the rising of the “ecological perspective” proposed by James J. Gibson (1972) and the neuroscientific approach that prevailed in the last decades of the XX<sup>th</sup> century. This strong connection between the discipline Fechner established 150 years ago and the directions psychology took in recent years can appear not so obvious anyway, at least at first sight. As John G. Neuhoff writes in a book on this subject by the same name (2004), an “ecological psychoacoustics” can seem like some kind of paradox, because of the superficial misconception too often held when thinking about psychoacoustics as it was practiced in the past. Anyway, the close relationship psychoacoustics and present psychological researches necessarily have to share can be found at least in three different reasons, perhaps obvious to the eyes of skilled psychophysicists, but no less important to highlight for the sake of a coherent epistemological analysis .

The first one - remembering Leonardo Da Vinci and the «*matematiche dimostrazioni*» needed to transform philosophical investigations into real science – is simply made up by the fact that psychoacoustics is the keystone which any complete psychology of music cannot simply exist without, as every act of musical cognition, like every behavioural, social and emotional response to the music totally depends on the human ability for perception of sound (and so our ability to remember, imagine and create music does). As a consequence, when we try to understand what, when and why humans or animals hear something (or react to something they hear), we first have to gain the best understanding as possible about *how* they do it at its most basic level, the mediation between a stimulus and a sensation. Starting from this axiome, it is clear how psychoacoustics had to gain more and more relevance in a theoretical frame that concentrated its attention on the deep relationship between mind, body, and the external world.

The second reason – as regards the new methodological approaches in scientific research - lays in the knowledge we have about the neuropsychological system, a knowledge continuously increasing as physiologists, neuroscientists and psychologists compare the results of their experiments, linking psychophysical, behavioral and cognitive data to each other, and consequently inferring better theories.

The third reason – the epistemic one we are going to discuss in this paper – is represented by the retrieval, more or less acknowledged, of Fechner's purest interpretation about psychophysics and its goals. It is undeniable that, through the 150 years that divide us from the publication of *Elemente der Psychophysik*, the discipline passed through several different paradigm shifts, shifts that exerted influences on - and that were influenced by - the theoretical models adopted by many psychological schools and movements. Moreover, it is also undeniable that these changes in perspective and methodology helped psychophysics to be an useful instrument of knowledge for the psychological research: and it is also true[?] that they often presented themselves as repeated proofs against Fechner's original formulations. However, through the lens of a historic-epistemological analysis, it seems correct to say that psychoacoustics' present state of the art, although its direct ties to some criticisms against the 1860 theory, holds a stronger connection with Fechner's views than it can be expected, because they share the same epistemic values. Briefly exploring some of the major issues concerning psychoacoustics (and psychophysics as well) of the last century, not just collecting and ordering informations, but rather searching for some kind of *fil rouge* in authors' words, we will try to point out how the epistemology that led Fechner to the brilliant “epiphany” of October 22 of 1850 has risen again, and totally fit into the theoretical approach underlying present researches in psychoacoustics and psychology of music.

### **An exact science of the acoustic world**

Let us start from today. For a comprehensive explanation about what ecological psychoacoustics is intended to be, we want to quote again John G. Neuhoff:

“The goal of this line of research has typically been to understand the complex higher order processes that occur when a listener hears a sound or intricate acoustic pattern. Clearly, lower level sensory processing is a prerequisite for both auditory cognition and perception–action relationships. However, the focus of many of these investigations is often on what might be called “listening behavior.” Identification, recognition, similarity scaling, and categorization are frequently employed methodologies. The results of these types of investigations often have implications that reach beyond simply perceiving music, speech, and auditory events. They may shed light on perception and action in other highly complex situations that involve overlearned stimuli. Those who study music performance, for example, may provide insight into other areas in which perception and the planning and execution of complex motor behaviors are intricately linked. The advantage of this approach is that it often comes closer to the listening experiences and behaviors that are encountered in everyday life.”

As it is clear from these words, ecological psychoacoustics focuses not just on the mediation between stimuli and sensations, but rather, it uses this lower level as a doorstep to higher cognition and sensori-motor processes, trying, at the same time, to establish a circular link, a feedback, between every element of the auditory processing, as a part of a more complex and integrated stream of cognitive, behavioral and neurobiological actions. Another epistemic data we cannot forget when we speak about the theoretical frame of present psychoacoustics and psychology of music – is the overcoming of the so-called “Descartes' error”, as proposed by Antonio Damasio (1994) not only because of its focus around emotions' origins and functions, but also for the definitive repeal of any kind of mind-body dichotomy (as we will see, rejection of Descartes' dualism represents perhaps the most important link between Fechner and modern psychoacoustics scientists). Even if these considerations can appear pretty obvious to those grown up into the theoretical frame of embodied cognition, it seems

important to us to point out this fact, because it gives a first basic clue to our epistemological analysis: contemporary psychoacoustics firmly keeps as its core the acknowledgement of the mind-body-nature intimate, unreduceable relationship. It is hard not to see the analogies this approach holds with the ecological psychology of music as proposed by Eric Clarke (2005), when speaking of the sensory system and its relations:

“reception must be understood as a relationship between environmentally available information and the capacities, sensitivities, and interests of a perceiver.”

In this theoretical frame, psychoacoustics become at the same time an instrument and an object of research. We can give an useful demonstration of this statement taking a typical experiment from ecological psychology of music, concerning the auditory localization into an open-field setting. Even if traditional psychoacoustics can provide some first explanations, it has to be related to the cognition of the specific auditory scene, to the behavioural functions it unleashes, as to the biological and evolutionary dimension of the listener, and then it has to be studied as a process influenced by the other ones, in a complex and integrated system (answering, for example, to questions like “How do I not hear the noise created by traffic when I listen to my friend’s voice? Why do I better recognize vocal sounds produced by my species? How do emotions exert influence on my ability to hear?” and so on). The acknowledgement of the continuous interaction between the three elements we mentioned above – mind-body-nature – stays at the core of modern psychophysics, and it share its place with the attention between the general, active interconnection between them. Anyway, this perspective is not a long standing acquirement.

### **An exact science of the acoustic body**

Perceptual theories until Gibson's “revolution” generally relied – apart from Gestalt theories - rather on a bottom-up processing hierarchy model, often excluding the cognitive, behavioral and emotional dimension of hearing. Of course, focus on the lower level let the psychoacoustician gain a better understanding of mechanisms of perceptual systems, allowing for the discipline to overcome psychophysics law and model how they were strictly expressed by Fechner. The most important step in this direction was made by the work of Stanley S. Stevens, perhaps the most influent psychoacoustician of the last century. In 1961, Stevens claimed that the mechanisms underlying sensory systems were not represented by a logarithmic function, as Fechner wrote in the *Elemente*, but rather by a power function, formulated in the law bearing his name. This result arrived about after ten years of researches in the field of psychophysics, preceded by the formulation of the theory of scale types, and the introduction of the division of sensorial continua in prothetic and metathetic continua. The epistemology of Stevens' psychophysics appears to easily match with the late behaviourist paradigm. In Stevens' words (1975), his psychophysics studies “the response of an organism, not some nonphysical mental stuff that by definition defies objective test”. His epistemic theory – that Stevens himself called *schemapiric* - lied in the process of definition of a formal system created through the analysis of empirical observations collected from experiments on the neurophysiological dimension of the listener. It is clear how this was the psychophysics version of Watson' “black box”, and it is also clear how this approach implicitly proposes a radical hardware/software dualism, limited by the focus on the physical part in relation with the outside world. Stevens himself reveals his point of view on the subject, in his *Handbook of Experimental Psychology* (1951):

“Measurement is an especial preoccupation of psychophysics – not only of psychophysics in the narrow sense of the term, but of psychophysics in its older and broader spirit, which tries to discover rules relating the responses of organisms to the energetic configurations of the environment.”

and in another work of 1966:

“I should like to press a precept that seems acutely relevant to the study of perception. When we study the input/output characteristics of an ammeter, we do not feel called upon to imagine how it feels to be an ammeter, nor do we try to relate our own experiences to those of ammeters. In the scientific study of man, especially in the study of operating characteristics of his sensory systems, many pseudo problems can be bypassed if we take the same objective attitude toward the human participant in an experiment as we take toward an ammeter.”

We know, through Stevens' own words in the famous 1961 article, *To honor Fechner and repeal his law*, how much the American psychologist considered the father of psychophysics. In fact, Stevens looked at himself as a perfecter of Fechner's law, able to give new scientific tenets to the discipline. However Stevens focused just on two of the three elements that modern psychophysics takes as necessary - body and nature - and he tried to formulate specific, invariant laws about their relationship, rejecting all those processes he couldn't directly observe and control. As a consequence, this approach presents two problematic issues. First, while a formulation of invariant rules can succeed in concept, it fails in implementation to everyday life, because it holds no consideration toward individual and environmental variations. Moreover, leaving no room for everything belonging to the “nonphysical”, Stevens left behind him an epistemic tenet of the original psychophysics: it has not to search for measurement, it has to search for relations.

### **An exact science of the soul**

Seventeen years after the publication of the *Elemente*, Fechner wrote:

“The Tower of Babel was not completed because the workers were unable to explain to each other how should they build it. My psychophysical structure will probably survive because the workers cannot see how they might demolish it.”

As we have just seen, history then revealed how Fechner's words were right only in part: many other psychophysicists, following the steps he walked for the first time, were able to recognize some structural mistakes and to correct the direction which Fechner considered the only one for the discipline to follow. Stevens was certainly the most radical in his proposal of a deep paradigm shift. But in his developing of psychophysics, he completely gave up the philosophical basis of psychophysics as Fechner conceived it.

Usually, in the history of psychology, a sort of ‘revolution’, a drastic emancipation of the study of mind from philosophy, is looked at as the starting point of scientific psychology. It is important to acknowledge the essential contributions given by physicists and physiologists around the middle of XIX<sup>th</sup> century to the emancipation of psychology from philosophy. But, as we go a little deeper in the interpretation of this historical moment, we have to clearly recognize that this “emancipation” has to be read more correctly as an evolution, aimed to move over from the limit imposed to the study of the mind by René Descartes, the mind-body dichotomy. Fechner's rejecting of Descartes' dualism is clearly exposed in the second volume of the *Elemente*, when the author writes about the interdependence between the physical and the psychical dimension of the human being. Descartes' dualism poses the most important and fundamental challenge to Fechner research, a challenge whose solution would have been the foundation of psychology as a scientific discipline: how could a science of the mind bring *res cogitans* into the scope of *res extensa*, where it could be observed and studied by the experimental methodology?

Moreover, answering this question in XIXth *Zeitgeist*, Fechner had to satisfy every parameter stated for real science by Immanuel Kant, who clearly posed the impossibility for psychology to become a proper science. Fechner found the solution to this problem concentrating his attention not in trying to measure sensations, but rather in searching for the relationship between it and the physical stimuli: if we can formulate this relation in a mathematical way (through the intuition of Weber), through the observation of variations in sensations related to exact stimuli's variations (as it was normal in the research field of physics), then scientific psychology can infer properties and laws of psychical processes. This approach, called “indirect psychophysics”, was rejected by Stevens, in favour of his “direct” psychophysics; but we think it is just on this basis that Fechner built up the most important part of his psychophysics' Tower. How he clearly wrote in the second volume of the *Elemente*, his epistemology was not aimed at finding a way to quantify the mental, but rather at formulating a theory sound enough to demonstrate the deep and active interconnection between mind, body and nature.

“The task (of psychophysics) did not at all originally present itself as one of finding a unit of mental measurement; but rather as one of searching for a functional relationship between the physical and the psychical that would accurately express their general interdependence.”

Focusing on this relationship, Fechner asserted that a “general interdependence” exists between the physical forces to which we mentally react (the “outer psychophysics” to which is devoted the first volume of the *Elemente*), as it exists also in a lower way between the same stimuli and our neurobiological system (the “inner” psychophysics of the second volume). While Weber's law can be applied without limitations into the field of inner psychophysics, there are some restrictions to its use into the realm of outer psychophysics. But, since it can be looked as a first understanding of the link between the physical and the psychical, it must be the starting point of every serious explanation of the relationship between mind and body:

“The determination of psychic measurement is a matter for outer psychophysics and its first applications lie within its boundary; its further applications and consequences, however, extend necessarily into the domain of inner psychophysics and its deeper meaning lies there. It must be remembered that the stimulus does not cause sensation directly, but rather through the assistance of bodily processes with which it stands in more direct connection. The dependence, quantitatively considered, of sensation on stimulus, must finally be translated into one of sensation on the bodily processes which directly underlie the sensation -- in short the psycho-physical processes; and the sensation, instead of being measured by the amount of the stimulus, will be measured by the intensity of these processes. In order to do this, the relation of the inner process to the stimulus must be known. Inasmuch as this is not a matter of direct experience it must be deduced by some exact method. Indeed it is possible for this entire investigation to proceed along exact lines, and it cannot fail at some time or other to obtain the success of a critical study, if one has not already reached that goal.”

On the basis of its criticism of pure cognitivist and operationalist models, ecological psychology of music has retrieved an important lesson Fechner taught to psychology at its birth, the heuristic power of the interaction between many different levels of research. “To honour Fechner”, modern psychology of music did more than repeal his law: it confirmed his epistemology.

## References

- Clarke E. (2005), *Ways of Listening: An Ecological Approach to the Perception of Musical Meaning*, Oxford: Oxford University Press
- Fechner G. T. (1860), *Elemente der Psychophysik*, Leipzig, voll. I & II.
- Fechner G. T. (1877), *In Sachen der Psychophysik*, Leipzig, p. 215.
- Stevens S.S. (1961), To honour Fechner and repeal his law, in *Science*, 133, pp.....
- Stevens S.S. (1966), Operation or Words?: A Reply to Savage, in *Psychological Monographs* 80: 33 – 38
- Stevens S.S. (1975), *Psychophysics*, Wiley, New York
- Neuhoff J.G. (2004), Ecological Psychoacoustics: Introduction and History, in Neuhoff J. G (ed.) *Ecological Psychoacoustics*, San Diego, California, Elsevier Academic Press, pp. 4 - 12