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A Perceptionist's View on Psychoacoustics

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Psychoacoustics is traditionally based on a world model that assumes a physical world existing independently of any observer – the so-called *objective* world. Being exposed to this world, an observer is impinged upon by a variety of *stimuli* reaching his/her sensory organs. These stimuli, if physiologically adequate, may cause biological transduction and signal processing in the sensory organs and its afferent pathways in such a way that finally a specific excitation of the cortex takes place, which results in *sensations* to appear in the observer's perceptual world. The sensations are understood as being *subjective*, since they require an observer to exist. This world model – also known as (objectivistic) *realism* – reaches its limits when it comes to explaining more complex phenomena of perception. Thereupon, in this paper, an alternative world model is emphasized and applied to psychoacoustics, namely the perceptionist's model. Like realism, *perceptionism* has a long tradition in epistemology. It appears to be suitable to improve our understanding of perceptual organization.

Keywords: psychoacoustics, perception, perceptionism, response, reality, stimulus.

1. Introduction

Acousticians usually refer to a world view which is strongly influenced by classical (*Newton*'s) mechanics. This is not surprising, because the physical section of acoustics is a branch of mechanics. This world model, known as (objectivistic) *realism* in epistemology, has a long philosophical tradition – e.g., (Descartes, 1641). It is assumed that there exists a world beyond perception which represents essential reality. This world is assumed to "*cause*" the perceptual world, but it is, by definition, never directly accessible. Whatever is perceived is, consequently, only an "*image*" of this (transcendent) real world, mediated by the sensory organs and limited by their imperfection. Taking this idea seriously, all percepts, consequently, lack essential reality. They are only a kind of illusion – in other words, subjective and shadowy. But, nevertheless, they provide a connection to the assumed real world such that we conclude by rational thinking that this transcendent real world must actually exist. The logic of the proof goes like this: If the transcendent world did not exist, also the perceived world would not exist. Yet, this conclusion is obviously logically questionable, as it recurs to an assumption that cannot be proven (a so-called "irrealis").

Nevertheless, isn't the assumption of a real world behind the perceived one justified by the fact that instrumental measurements methods are available that render results which are independent from specific observers and thus, assumingly, must exist independently of any observers? Aren't these instrumentally collected data free of any perceptual distortion and can thus be used to build a valid model of a "real" world?

This is indeed the world view of *realism* and, actually, it carries a long way, particularly in applied physics and engineering. Yet, unfortunately, it leads to substantial conceptual inconsistencies when applied to research into perceptual phenomena, because, along these lines of thinking, perceptual phenomena are conceived as subjective and illusionary in essence – and, hence, an ill-defined item to investigate scientifically.

The basic inconsistencies appear clearly when analyzing a philosophical problem known as the *retinal-image problem* (Becker, 1978; Blauert, Guski, 2009). Although taken from vision, we shall use this epistemological problem as an example here because of its very illustrative nature. The results of the analysis can easily be extrapolated to any other modality, such as audition, touch or proprioception.

1.1. The retinal-image problem

Visual perception – heavily simplified – is usually explained as follows: From the outside world, light rays enter the eyeball and, with the eye acting like a CAMERA OBSCURA, a "photographic" picture of the outside world is projected onto the retina, the *retinal image*. The retinal image (in physical terms, a pattern of electromagnetic waves) is the adequate stimulus for the visual system, that is, it stimulates sensory cells in the retina to send biologic signals upward the afferent neural pathways. These signals, after various processing steps, finally reach the visual cortex, where an adequate excitation pattern is somehow generated. This pattern triggers a conscious visual percept to appear in the observer's world. The details of this process are still considered enigmatic – and may stay so forever.

The problem within this model is best illustrated by an experiment of thought: Ophthalmologists, as is well known, can visually inspect the retina with special optical equipment. In doing so, they are able to see the retinal image. Now consider an optical equipment (realized, e.g., by mirrors, lenses and/or fiber optics) that allows persons to inspect their own retinas themselves. Wouldn't they then see retinal images which cause themselves, that is, are stimulus and sensation simultaneously and in one?

Since it is unacceptable from a logical point of view that an item "causes" itself (causa sui), there must be something wrong, and speculation may go as follows: The retinal images that the test persons see, are not the ones that actually cause them. There must have been earlier ones that did so. But when we would have tried to observe those earlier ones, they would have been images as well. Can images cause images? No, one could say, it is the electromagnetic wave pattern behind them. But haven't these wave pattern been detected with instruments that are also part of the perceptual world and, therefore, are "images" as well?

Obviously, the realist's world model raises fundamental epistemological doubts regarding its validity. Furthermore, from the point of view of psychoacoustics as a science, it has the disadvantage of classifying the research items of psychoacoustics, namely, auditory percepts, as suffering from a lack of essential reality and thus being principally inaccessible by exact sciences. It is therefore surely in the good interest of psychoacoustics to watch out for world models which do not have these disadvantage. Thus, *perceptionism* will now be considered and discussed as an alternative.

2. The perceptionist's world model

Perceptionism is a world model that, like realism, has a long philosophical tradition – compare, e.g., (HUME, 1740; KANT, 1781). Perceptionism puts to the fore what is consciously perceived, that is, the percept itself. In view of this model, the totality of percepts is the essentially real world. The conceptual foundation of perceptionism is expressed by a famous statement of BERKELEY (1710): "*esse est percipi*" (to exist is to be perceived). Accordingly, "to exist" and "to be perceived" are synonyms. In perceptionism, the world is understood as being completely describable and interpretable within the perceived world. Any (epistemologically questionable) assumption of transcendent worlds is thus considered superfluous[1]. From the point of view of psychoacoustics (and psychophysics at large) auditory events and acoustic events are both percepts and, ergo, basically represent the same amount of essential reality. As one percept obviously cannot "cause" another one (how should this be accomplished without witchcraft?). Thus, the perceptionist's view requires a reconsideration of the traditional stimulus/response paradigm.

Modern perceptionism has a strict biological foundation by recognizing the brain as the sole organ of consciousness (e.g., LUNGWITZ, 1947; MATURANA, 1978). This implies that each and every percept corresponds with a specific physiologic state of the brain. This holds as a one-to-one mapping, because brains as everything else in the world are in a state of steady transition and will never be exactly the same again (compare *Herodot's* $\pi\alpha\nu\tau\alpha' \rho\tilde{\varepsilon}\iota$

2.1. Perceptual organization

To apply a perceptionist's view to problems and tasks in psychoacoustics, a model of the perceptual organization of the world is needed. To this end, the totality of percepts may be grouped into different categories. Following a concept of LUNGWITZ (1947), suitable categories are *feelings, things* and *concepts*.

Feelings normally occur when sensors inside the body are activated, and they are usually perceived at or close to the positions of the sensors (e.g., stomach pain, fear in the heart). In special cases, feeling can also be located outside the limits of the body, for instance, phantom pain after amputation of limbs.

Things (sensory percepts, sensory events) for example, auditory, visual, or tactile or proprioceptive ones (LUNGWITZ, 1947; BLAUERT, DOMINICUS, 2013; BLAUERT, JEKOSCH, 2012) usually appear while sensory organs are active. They are mostly located outside the body, but in special cases they may also be inside – like tinnitus in the ear or light speckles in the eye

[1]Perception implies both a perceiver (observer) and what is perceived (percept). KANT (1781) has therefore introduced a conceptual observer as counterpart of the percept. It has been clarified (see LUNGWITZ, 1947; DOMINICUS, 2009) that this conceptual observer cannot be further analysed, since the polar opposition to any existence is non-existence. Something that exists, always exists as a polar counterpart to non-existence. This conjunction-in-opposition cannot be broken up.

due to a sick headache. Further, coordinative percepts (position, direction and strength) may be subsumed under sensory perception (see proprioception). Sensory percepts are modality-specific, that is, they are either auditory, visual, tactile, gustatory, olfactory, or coordinative.

Concepts (ideas, notions, thoughts) are associated with feeling or things, but do not directly originate from signals sent by body-internal sensors or sensory organs. In essence, concepts are more or less abstract remembrances of feelings, things or other concepts. On the one hand, they are certainly percepts themselves, on the other hand, they are pointers to other percepts[2].

3. The paradigm of psychoacoustics

In the following, the relationships between acoustic stimuli and auditory events will be discussed, since these are the primary item of psychoacoustic research.

In this paper, we shall argue solely on the basis of things and concepts, leaving out the feelings at the time being for the sake of simplification, although feelings, to be sure, are a very important category of percepts.

The commonly used experimental paradigm in psychoacoustics is shown in Fig. 1, which schematically represents a listener in a hearing experiment (Blauert, Guski, 2009). The input is given by a "stimulus" (acoustic event), S, in our case a sinusoidal acoustic wave. If this wave is in the range of hearing and the listener has a functioning auditory system, he/she will hear something, that is, in his/her world appears an auditory thing (auditory event), T. Yet, as this thing exists in the world of the listener, an outside observer can only get to know of it through an observable response, R, of the listener.

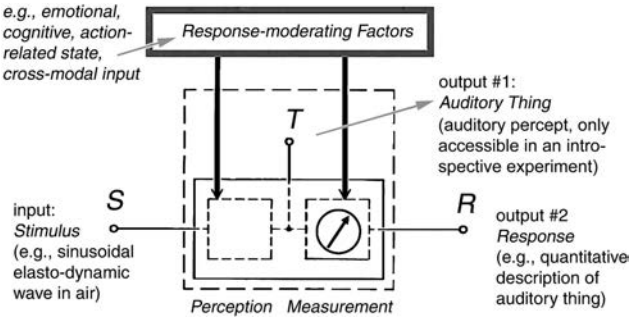

Fig. 1. The paradigm of psychoacoustical experiments.

[2]Perceptual categories are confluent, i.e. the borders between them are not strict. This is also reflected by the terminology used to describe them. For instance, the term "sensations" is used for sensory percepts (things) in psychology, while in colloquial language it is also used for feelings. Yet, the term feelings, used here in the sense of emotional responses, can in colloquial terms also mean the sense of tactility, i.e. what is felt at the skin when touched.

In psychoacoustics, the listeners are instructed and trained to respond by way of quantitative judgment upon perceptual attributes of their auditory events. Specifically, they are requested to assign numbers to attributes of what they hear. If the assignment of numbers to the perceptual attributes of auditory events actually reflects these attributes in a valid way, then this procedure can be taken as a measurement. In fact, the listener, who now assumes the role of an assessor, has two roles in the game: First, his/her auditory perceptual system is the item to be measured, secondly, the assessor him/herself is the measuring instruments to actually perform this measurement.

Since both, perception and measurement, are dependent on the assessors' individuality, the actual experimental situation and the mental state that the assessor is in, some models assume "modifying factors" to take account of these effects (e.g., Guski, 1999). In the following, the psychoacoustical paradigm of Fig. 1 will be evaluated from a perceptionist's point of view.

3.1. The "stimuli"

In psychoacoustics, the stimuli concerned are acoustic ones – "acoustic" meant in its physical sense, that is, vibrations and waves of elastic media. Vibration and waves are coordinative variation of matter. If very slow, we may see them or sense them by touch, if faster, we detect and measure them instrumentally. Note that *audition is not at all involved so far* (Blauert, 2006; Blauert, Jekosch, 2012).

From thinking about such visual and tactile perceptions and other relevant observations, a physical theory of mechanics has evolved – in its classical form – *Newton*'s mechanics. For instance, physical concepts like mass and force have been developed, leading to even more abstract concepts like, for instance, the wave theories of sound propagation in fluids and solids. Nevertheless, to be sure, the physics of mechanics is originally based on visual and tactile observation and successive thinking. In other words, it is a conglomeration built from visual/tactile things and concepts – surely percepts all together. Consequently, physical objects like *elasto-dynamic waves and vibrations are concepts and not things* (!), but nevertheless percepts. This obviously holds also for the acoustic stimuli in psychoacoustic experiments.

How come then that in terms of the world model of realism, physical objects are assumed to exist outside perception and thus being "absolutely objective". To discuss this, the meaning of objectivity has to be recollected first. In empirical sciences, the results of an experiment are considered objective if the results do not depend on specific observers. This actually means that you may bring your experiment to a different laboratory with different experimenters, and they would still get the same results.

To get as close as possible to the goal of objectivity, physics has "cultivated" instrumental measuring equipment to render result where the influence of the individual experimenter is minimized[3]. Further, physical theories are based on mathematics, that is, the results of physical experimentation are interpreted and described in mathematical terms. If experimental results differ from what is theoretically (mathematically) predicted, the differences are classified as "errors" and often disregarded. But note that mathematical thinking is governed by standardized logic rules. If two mathematicians come to different results with regard to a mathematical problem, at least one of them has violated the rules. In this way, mathematical thinking is certainly signified by a high amount of objectivity, but when experimental results are forced into a mathematical, that is, a conceptual framework, the achieved objectivity is conceptual as well – and certainly not "absolute" in any way.

All this can be dealt with within perception. An extrapolation to a transcendent world is not necessary. We do not need the notion of absolute objectivity at all. The amount of objectivity of an experimental result can be marked on a polar scale reaching from utmost objective to utmost subjective. Utmost subjectivity means that no two assessors agree on a result, utmost objectivity that all potential assessors would agree.

3.2. The auditory "things"

What listeners sensorily perceive in the course of listening experiment *exists* in their world *as being heard*. This is what we call the auditory things. Like any other things, they exist at specific times at specific locations, attributed with specific (auditory) features.

Classical psychoacoustics aims at assessing the relationship between features of the (physical) stimuli and features of the auditory things in a quantitative way. To this end, so-called "psychometric" methods have been developed that enable assessors to assign numbers to auditory features in such a way that relations between numbers reflect relations between the features under observation. These methods enable measurements of thresholds of perception, difference limens, points of perceptual equality, further, they allow for direct estimation of intervals, ratios and magnitudes.

In the attempt to measure auditory features in their "pure form", the according listening experiments are designed in such a way that the measurements are, hopefully, not biased by any conceptual context. For instance, signals are used that do not carry explicit meaning (sinusoids, complex tones impulses, noises, etc.). Further, the assessors are not provided with any contextual information (e.g., the nature of the sound source, the scenario and its history). Auditory features that have been investigated in this way are, for instance, loudness, pitch, sharpness, roughness and spatial extension. Yet, to be sure, context free perception does not really exist (Blauert, Guski, 2009). Already a "context-free" experiment is a context. Also, mind that auditory features are attributes of auditory things and not things themselves.

In any case, when assessing auditory features, the listeners have to be in an analytic (discretic) listening mode, concentrating on just the feature under observation and disregarding auditory things as a whole. However, humans are usually in a holistic (syncretic) listening mode, that is, attending to larger perceptual entities than auditory features or even auditory things. Cognitive psychology argues that the human brain, as a rule, does not think in sensory percepts (things) but in "objects". Objects are perceptual entities that represent an agglomeration of direct sensory input and conceptual reflection. Hence, to understand auditory perception in a more comprehensive way, the processes of object building need to be considered and understood. In this context, the well known *Gestalt* rules are, for instance, relevant. Numerous further "schemata" have been identified by psychologists to be involved in the neural processes of object forming.

From the point of view of a perceptionist, these processes do not pose any epistemological problem. Both sensory percepts (things) and concept are "brainchilds", that is, are bound to physiological processes in brains. Objects can be understood as conceptual constructs that result from agglomerating intercurrent series of things and related thoughts. Objects, thus, are perceptual entities of their own, but represent the underlying sensory percepts and the related reflections in a more abstract way. The same processes, by the way, also hold for "physical" objects (see Sect. 2.1), they are also conceptual constructs, that is, a particular kind of percepts.

Consequently, when analyzing and interpreting auditory things, it is necessary to see them in their perceptual context. Things have attributes that can be assessed separately, but even more so, things are elements of the formation process of objects – the actual building bricks of the world in perceptual terms.

This means that classical psychoacoustics can only render limited insight into the correlation between physical and auditory aspects of our world. In other words, its prognostic power when predicting auditory events from their physical correlates is limited. The common excuse is that the prediction errors are due to the subjective nature of auditory things in contrast to the objective nature of physical objects. This excuse will only be accepted by a perceptionist when phrased as follows: Physical objects are perceptual constructs

[3]In modern theoretical physic it has been realized that the item of observation may change with the actual kind of observation – another case against "absolute objectivity", that is, existence indepent from the observer.

that have been derived from results of measurements that are largely independent of specific observers, that is, which are rather abstract concepts. In contrast, auditory things have a much lower level of abstraction and are, consequently, more individual. Hence, physically measured data may certainly provide rough, general estimates of auditory attributes in specific, well defined situations. However, they show a severe deficit in terms of validity when it comes to the prediction of auditory things or even auditory object in specific situational contexts.

To increase the validity of the prognosis, processes have to be taken into account which classic psychoacoustics cannot unravel. Here knowledge from sensory psychology has to be taken into account, verified or at least supported by neurological findings to maintain the link to the biology of the brain and thus, to ensure the scientific foundation of the model. The "modifying factors" as introduced in Fig. 1, are really only a very rough approach to deal with this problem.

This means, among other things, that the classical psychometric methods have to be amended. Two different aims of measurement can be distinguished in this context, (i) analysis of auditory objects and scenes to identify and scale their different perceptual attributes individually, (ii) assessment of holistic features of auditory objects and scenes, for instance, the sound quality assigned to them by listeners. For measurements of type (i), method like the semantic differential or multidimensional scaling are applied, for type (ii), paired comparison or direct magnitude scaling on one-dimensional interval or ratio scales are in use.

Note however, that for the perceptionist all these measurements take place within the world of percepts. An extrapolation to a transcendent world beyond the perceived one is not obligatory to understand the latter.

3.3. The "responses"

Auditory things are directly experienced by the listener whose percepts they are. For an observer of this listener, these auditory things are not directly accessible, but only indirectly via the response of the listener – which can, for instance, be a spoken verbal description of what he/she hears. The observer then concludes that there exists a perceptual world for the listener and that there are auditory things and/or objects in it.

A realist could now argue with the perceptionist as follows: On the basis of the response of the listener, you conclude that there exists a perceptual world of this listener to which you principally do not have direct access. Isn't the listener's world just such a transcendent world as you otherwise try to deny? The perceptionist's answer is as follows: My directly experienced percept is, of course, the response of the listener and not the listeners' auditory thing. So, the item which is a *fact of direct experience* for the listener, is only a *fact of description* for me, the observer (Lungwitz, 1947). The listeners' auditory things are thus concepts for me and not things – yet, without doubts, percepts in any case. These concepts arise as a conclusion from what I hear as a spoken message, that is, from auditory objects in my world. An extrapolation to the existence of a world beyond perception and, thus, beyond the biologic capabilities of the brain, is logically not imperative.

After having introduced a distinction between facts of experience and facts of description, it is interesting to have a closer look at the attributes of those auditory things that relay facts of description, and on the subsequent concepts which represent them. This concerns the scientific fields of communication sciences and, particularly, of semiotics (the theory of signs).

It is a generic task of the auditory system to act as a kind of antenna with a subsequent processing stage to provide the brain with input for the formation of its perceptual world. In this way, for example, the identification of sound sources in the environment regarding their temporal and spatial position can be explained. Further, the auditory system is of paramount importance for inter-individual communication – in human beings mainly via speech (spoken language).

Generally, it can be stated that all auditory things and, thus, also the acoustic stimuli as being correlated with them, can be conceived as sign carriers that relay information about the world. As a consequence, meaning may be assigned to the relayed signs. It is the specific schemata that underlie these processes of thinking which are investigated by semiotics.

Semiotic teaches that three requisites are indispensable for the assignment of meaning to happen, namely, an auditory thing, a listener and a conceptual reference. Only when these three components are present, signs can be understood, that is, a meaning may become apparent. By the way, audio engineers, sound designers, and also composers and musicians, etc., can be seen as engineers of aural communication. They provide sound signals which lead to auditory things that carry meanings, which are, hopefully, understood by the listener as intended.

The processes of meaning assignment are complex. For instance, when spoken language is understood, the auditory things have been identified as speech sounds (phones) and as belonging to a certain language (allophones), and these have then been interpreted on the word and sentence levels. Thereby phonetic, syntactic and grammatical rules have been observed and prosodic characteristics have been considered. Of course, as a further condition of successful meaning assignment, the vocabulary used must be known to the listener.

In any case, the interpretation of acoustic and auditory "cues" requires cognitive processes at a higher level of abstraction. It is thus not surprising that in

semiotics a notion is put forward as to which the conceptual interpretation of the world is primarily based on signs, their recognition, interpretation and a subsequent assignment of meaning. Thereby the interpretation of known signs may well become a routine operation after a while, and the assignment of meaning is then conceived as a schematic process in these cases.

The semiotic way of interpreting the world is highly important for the predictions of actions (and reactions) of people, since people usually do not act and judge upon what they hear and where they hear something, but rather on what they hear actually means to them in their individual situation.

Signs can have the character on an *index*, an *icon*, or a *symbol* (Jekosch, 2005). An index is a copy or slightly modified copy of a sound as originating from a particular event, for example, the breaking of a drinking glass when falling from a table. An icon represents an abstraction from of the original sound in such a way that a simplification has taken place, but the relevant features have been preserved or even enhanced. A symbol has not necessarily any direct relationship with the event that it symbolizes. Therefore, the relationship between symbols and what they symbolize has to be learned, as, for instance, the relationship of *Morse*-code units and the letters that they symbolize. Indices, icons and symbols are concepts, and thus percepts from the perceptionist's point of view. They differ in the amount of abstraction from their underlying sensory percepts, namely, the auditory things which they represent. While indices relate to individual events, icons do so for a class of events in a more abstract way. Symbols, finally, abstract completely from their perceptual roots. Their meaning is originally arbitrary and must therefore be deliberately assigned, and then be learned.

When it comes to measurement of the meaning that auditory things communicate, the traditional methods of psychoacoustics and sensory and cognitive psychology are rarely helpful. If methods like the semantic differential or multidimensional scaling are applied at all, the scenarios in which they are applied must represent real communication scenarios. More adequate are questionnaires and behavioral tests in representative situations as, for instance, applied in cognitive psychology and the social sciences.

4. Discussion and conclusion

In this contribution we promote a world view that is different from the objectivistic *realism* which is usually favored by engineers. This alternative is *perceptionism*. The basic ideas of both, objectivistic realism (also discussed as, e.g., scientific realism or positivism) and perceptionism (also discussed as constructivism or concientialism), have a long tradition in epistemology.

Perceptionism is based on the notion that to be perceived and to exist are synonyms (Berkeley, 1710). Any assumption of existence beyond perception, that is, existence independent from observers, is discarded as a game of thoughts without any empirical evidence. Thus, in the perceptionist's view, "absolute objectivity" does not exist. Even physical objects are unmasked as perceptual items, namely, as a conglomerate of visual and tactile percepts plus successive theoretical thinking.

To develop logical consistence of the perceptionist's model, two issues have to be realized:

- Concepts (thought, ideas, concepts, notions) are real percepts and not in any way enigmatic, shadowy items. In particularr, concepts are percepts that point to other percepts. They essentially are remembrances, although more or less abstract ones [7, 15, 16].
- It is necessary to distinguish between facts of experience and facts of description. While auditory things in my own world are facts of experience, auditory things in the world of somebody else are (only) facts of description in my world – but nevertheless percepts.

A driving reason to look closer into the perceptionist's world view is the following: Since perceptionism puts physical objects at the same epistemological level with auditory things and concepts – actually unmasks them as being concepts (constructs), any discrimination against psychoacoustic as an assumingly absolutely subjective science looses its substance. In fact, physics itself is recognized as being basically perception-based. *Objectivity is thus identified as being relative in essence, so is subjectivity.*

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