Sonosemantics

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Abstract
The purpose of this positioning paper is to propose a new definitional framework of sound, *sonosemantics*. The need for this is apparent for a number of reasons. Physiological conditions such as some forms of subjective tinnitus require no sound waves for sound to be heard yet all current mainstream definitions of sound state that sound is a sound wave or that sound requires sound waves for its perception. New research suggests a closer and directly causal identification of sound with emotion than hitherto uncovered. New technology suggests new ways to exploit the possibility of hearing sound in the absence of sound waves.

Keywords
Sonosemantics, Sound, Emotion, Meaning.

ACM Classification Keywords
H.5.2 [**Information Interfaces & Presentation**]: *Theory and methods.*

General Terms
Design, Human Factors, Theory.

Introduction
The purpose of any definition is to provide a handle on some concept so as then to be able to make use of it either philosophically or practically. We believe the new definition of sound presented here to be a particularly useful one as it helps to explain a number of phenomena not explained by current definitions of

sound. It succinctly makes use of and incorporates key elements of current philosophical and scientific thinking and it has practical purpose as a tool to further the design of sound experiences in a variety of situations.

We take our cue from the philosophical concept of the virtual as potential, a mode of reality that is made real and perceptible (an emergent perception) under certain conditions pertaining to space and time (see [8] and [9], for example). A conception of sound as arising from actual and virtual sonic phenomena allows us not only to incorporate the previous definitions of sound but also to account for the potentiality that lies within our processes of cognition and emotion.

What is of interest to us, therefore, is the investigation of the conditions under which actual and virtual sonic phenomena can be realized as an emergent perception of sound and this requires a new definition of sound.

Some previous definitions of sound

Sound as sound wave

Traditional acoustics treats sound as a sound wave with the main physical parameters of frequency and amplitude. This is certainly a useful definition of sound that has proved to have practical purpose; once the physical properties have been analysed, sounds can be digitized, processed, synthesized, or stored.

The location of the sound wave source can also be inferred with our stereophonic hearing through a comparison of amplitude difference and/or time of sound arrival at our two ears. Additionally, there is some evidence from the field of ecological acoustics that our brains are evolutionarily attuned to respond to certain combinations of frequency and amplitude where they may concern threat [6].

Sound as property of a vibrating object

This equation between frequency/amplitude and proximity and/or size of potential threat finds resonance in two other current definitions of sound. One is the view that sound is the property of a body and is heard when that body vibrates [13]. This is a view that, in various forms, dates back to Aquinas in the 13th Century (although echoes of it can be found in earlier philosophy).

Locke held to the view that sound is a property of a vibrating body although it is unclear whether Locke was referring to solid objects (such as bells) or to the medium of air with the use of the term 'body' (see [11] for a discussion of this). Pasnau, though, is quite clear that sound is the property of an object rather than the medium through which sound waves travel. Because hearing is a locational sense, sound must therefore be located at its source and thus is "among the various sensible properties of objects: among colour, shape, and size" [13].

The vibration of an object, its frequency and amplitude, bears some relation to the object's dimensions, its density and elasticity, and, dependent on the material, the macro-structure of the material itself. This provides support to Hermann and Ritter's suggestion of evolutionary habituation to particular combinations of frequency and amplitude.

Sound as event

A definition provided by O'Callaghan is that sound is "the act of one thing moving another" [12]. Thus,

sound is an event and a sound wave is merely the effect of a sound: "Sounds are events that take place near their sources, not in the intervening space" [12].[1]

Limitations of current definitions of sound

The acoustics view that sound is a sound wave states little about other aspects that might also be deemed to be important to understanding sound; for example, the sound's source and the environment the sound occurs in and is affected by. More importantly, though, it says nothing about the experience of sound, its affective effect or any meaning that is associated with or is part of the sound. As Gibson states: "[Traditional acoustics] treats physical sound as a phenomenon *sui generis*, instead of as a phenomenon that specifies the course of an ecological event; sound as pure physics, instead of sound as potential stimulus information" [3].

As the vibration of an object can often be sensed through touch (and, as in the case of loudspeaker diaphragms, can often be seen), it is therefore sensuous and material and so is an instance of an actual sonic phenomenon. Where the vibration cannot be sensed in this manner, it may still give rise to actual sound wave phenomena.

As with sound as a property of a vibrating body, we also count the view of sound as an event as a sensuous and material phenomenon where the event can be seen or felt. Likewise, if it cannot be sensed in this manner, the event may give rise to secondary actual sonic phenomena, sound waves.

1 It is not clear what this intervening space is if this is where O'Callaghan places sound waves because sound waves typically propagate well beyond the space that exists between the one thing and the other that is moved.

An issue with all three of these definitions of sound is that they are defined as actual phenomena that must be sensed and, furthermore, not only is the acoustic view of sound founded upon sound waves, but, in order to be perceived, sound as described in both the object view and event view, must be transduced into acoustic energy in the form of a sound wave.

This is where our definition of sound differs to the three presented here. The definition we present does not necessarily require the presence of sound waves for a sound to be perceived and it takes account of what we would call virtual sonic phenomena, those phenomena that are based upon cognition and emotion and that are used, rightly or wrongly, to interpret the source and/or meaning of the sound.

Some evidentiary considerations

Embodied cognition

When considering our definition of sound from an embodied perspective the most relevant aspect of this theory is that of an integrated system of mental processing within which the internal physiology of the listener and their external environment are requisites for characterising and comprehending sound. Without embodied factors a soundwave is to a sound, what a binary sequence is to a digital image.

Role of emotions

The potential impact of emotional state upon auditory perception adds further credence to our definition. Circumstances in which extreme stress or anxiety have attenuated or amplified the perceived amplitude of a sound are well documented and emotional influence can also be attributed to motivation and attention during listening. For example, the cocktail party effect

(filtering of competing waveforms to focus upon a single source) could be related to emotions by way of attention, to motivation, to desire and then to excitement of happiness. In this scenario an individual would be motivated to attend to a specific source by way of their desire to cultivate a social relationship that bestowed upon them a positive emotional sensation.

Tinnitus
A sizeable minority of the population suffers from the condition tinnitus including the subjective form, which is what concerns us here. The cause of the tinnitus does not matter; what matters for our purposes is that the sounds heard in many forms of subjective tinnitus are sounds in the absence of sound waves. We cannot propose that such sound is the property of a vibrating body because there is no vibration that takes place. Nor can it be viewed as a sound event because there is no one thing moving another thing.

Auditory illusions
Augoyard and Torgue present various scenarios in which sound is perceived but not in direct response to an acoustic waveform [1]. So-called auditory illusions include phonomnesis (an imagined sound unintentionally perceived as real), remenance (the sensation of a continuation of sound after the waveform has ceased), and the Tartini effect (a combination of tones that creates the sensation of an additional frequency that is not present as a physical waveform). In a similar vein, established psychoacoustic phenomena that include Shepard tones and sonic masking elucidate ways in which the perceived sound (the sound that is heard) and the acoustic waveform data (the sound that is propagated) do not correspond.

Mirror neurons
Research looking to observe patterns in neural activity between physical actions and relative sensory stimuli has discovered that such correspondence applies also to auditory sensation [7]. The association to our definition of sound is derived from our proposition that mirror neurons create a multi-directional relation between modalities of experience and therefore could clarify particular circumstances of auditory illusions. For example, remenance could be explained as continuing mirror-neuron activation responding to an audio-visual stimulus in which the audio has ceased but the visual stimulus remains.

Cross-modality
One critical notion behind both the acoustic ecology of the first person shooter [4] and the embodied virtual acoustic ecology [5] is that information received from other sensory modalities has the potential to influence the perception of an acoustic waveform, both in terms of our autonomic and affective responses to the sound, and in the appraisal data we extract from the sound via cognitive evaluation. The classic psychoacoustic phenomenon relevant to this issue would arguably be the McGurk effect [10] in which artificial overlay of an unconnected visual element over a soundwave would alter what sound was actually perceived.

A new definition of sound: Sonosemantics

There are a number of reasons listed above that lead us to suggest a new definition of sound and thus a new approach to its study and its use. Current definitions of sound are insufficient in their premises to comprehensively include all our experiences and understandings of sound. What we think of and experience as sound does not necessarily require the

physical stimulus of sound waves.[2] Expanding our definition of sound to include these other experiences opens new pathways not only to the exploration of these sound experiences but also to the ways in which we can then utilize sound.

Current research is making inroads into understanding our emotional response to sound and, in particular, quantitatively identifying psychophysiological patterns that match the qualitatively reported experience of emotions in response to sound [2]. To this end, we use this final section to propose a new definition of sound that is a perceptual view in order to lay the groundwork for a new field of study that we term sonosemantics.

The preliminary sonosemantic definition of sound that we propose is:

Sound is an emergent perception arising primarily in the auditory system that is realized through the phenomenon of temporal change in an embodied environment

This can be explained as:

- *Sound is an emergent perception . . .* The two key words here are emergent and perception and the last is probably the most contentious. With perception, we locate sound as a phenomenon within our mind, as something that is dependent wholly or in part on cognition and emotion and this perception does not necessarily require sensation. Thus, a sound does not require a sound wave (a material, sensuous and actual sonic phenomenon) for it to be perceived as a sound. Emergent relates to the present and on-going act of sound perception in the here and now; *the hear and now of sound*.
- *. . . arising primarily in the auditory system . . .* The emergent perception of a sound is initiated in the main in a corporeal system that comprises the ear and auditory cortex. Factors that lead to the sound perception may derive from outside the immediate body, within the wider environment and be sensed by the peripheral auditory system (the ear initially), they may arise from inside the ear itself, they may spring solely from within the brain and may involve only a part of the auditory system in the act of perception, or they may arise through the effects of cross-modality. Within the brain itself, other systems such as those involved with emotion and non-auditory cognition, will contribute to the act of perception.
- *. . . that is realized through the phenomenon of temporal change . . .* Sound is an emergent perception that takes place over time but, more than this, the stimuli giving rise to such perceptions are time-based. Such stimuli may include sound waves that are propagated over distance and through time and that themselves can be analysed acoustically in terms of change in relation to time either as a composite sound wave or as a number of component sound waves. Other forms of stimuli may occur such as those that give rise to a particular type of tinnitus where sound perception takes place in the absence of sound waves.
- *. . . in an embodied environment*. We take the view that our perception and senses are indivisible from the wider environment, a view that finds expression in the

2 A language such as German makes a distinction that English does not: *Schall* is sound as a sound wave; *Klang* is the general experience of sound and includes imagined sound. Nevertheless, the current academic *lingua franca* is English.

field of Embodied Cognition. Following on from this, perception is a body-based function and thus inseparable from that body rather than being a separate component to functions such as emotion.

Such a definition is accommodating of several aspects of other definitions of sound. With the exception of not defining sound as a sound wave, it encompasses the role of factors such as pitch/frequency and loudness/amplitude and the subjective nature of these, the cognition of sound through stimuli produced by vibrating bodies or the event of one thing moving another, and cognitive functions. It also allows for the possibility that we are evolutionarily predisposed to respond to sound in basic, pre-programmed, and common ways.

What we have presented here is a new definitional framework of sound as a means to explore further our understanding of sound and our experience of it and also to expand its utilization possibilities. Much work remains to be done to test this framework, but the conceptualization of sound in this way allows us, in particular, to explore any direct relationship between sound and cognition and emotion and this, in turn, might lead to new paradigms for the design of auditory interfaces and other sonic experiences.

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