ELVIRA DI BONA
Università Vita-Salute San Raffaele / Institut Jean Nicod
elviradibona@email.it

SOME CONSIDERATIONS ON PITCH

abstract

Pitch is an audible quality of sound which can be explained not only in terms of strong correlation with sound waves' properties, but also by a neat correlation to the properties of the sounding object. This seems to be in favour of the theory of sound labelled "distal view", according to which sound is the vibration of the sounding object.

keywords

Sound, perception, pitch, sound sources

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ELVIRA DI BONA *Università Vita-Salute San Raffaele / Institut Jean Nicod*

The medial view of sound says that sound is identical or supervenient upon sound waves in a medium (Nudds 2009; Smith 2009; Sorensen 2007, 2009). The distal view (Casati and Dokic 1994, 2005; Pasnau 1999, 2000; O'Callaghan 2007, 2009; Kulvicki 2008; Matthen 2010), on the contrary, claims that sound is located where sound sources are and that sound is the vibration of the sounding object. Generally speaking, as regards pitch, loudness and timbre at least, audible qualities are perceptual properties which are explained by the presence of strong correlations with some properties of waves and, therefore, they are sufficiently explained by the medial view. On the contrary, it seems that if we identify sound with the vibration of the sounding object, we cannot give an account which correlates the audible qualities with the properties of the sounding object. In this essay I shall focus on the audible quality of pitch in order to show that pitch can not only be considered as the perceptible counterpart of the physical properties of sound waves in a medium, but that also it correlates to the physical properties of the vibration of the sounding object. I shall conclude the essay with some remarks regarding the fact that pitch lets us grasp a number of features of the sound sources which produced it.

This essay is divided into four sections. In the first section, I formulate the three questions which we should answer in order to define the relationship between the audible qualities of sound and the properties of both sound waves and sound sources. In the second section, I give a general response to the first of these three questions. In the third, I clarify some issues related to the possibility of having sound in a vacuum. In the last section, taking into account the example of pitch, I answer the second question formulated in the first section. I shall leave the answer to the third question for further investigation.

1. Three Questions Regarding the Nature of Audible Qualities

Imagine you are in a concert hall, listening to the beginning of the first movement of Max Bruch's *Violin Concerto n.1 in G minor*, and that the sound you hear is the sound of a violin, playing a G3 in *mf*,[1] with a fermata on the note (the fermata indicates that the duration of the note is at the musician's discretion). You would note that the sound you hear has some features,

1 In music notation the signs *ppp*, *pp*, *p*, *mp*, *mf*, *f*, *ff* and *fff indicate* the dynamics of a composition.

namely timbre, pitch and loudness which are commonly called the "audible qualities" of sound.

It is usually asserted that sound possesses audible qualities and that it is by virtue of our capacity to attribute such qualities to the different sounds which form our auditory scene that we are able to group the undistinguished sound streams into distinct streams (Bregman 1995). Generally, these qualities are defined in terms of sound wave features. Assuming, however, that sound is an event source which can also take place in a vacuum (Casati, Di Bona, and Dokic 2013)[2] and considering that we cannot have sound waves in a vacuum, it appears that there might be a problem in attributing audible qualities to sound.

Therefore, in order to clarify such a delicate point, it might be useful to address three questions. The first concerns the relationship between the audible qualities of sound and sound waves; the second, the relationship of audible qualities to sound sources while the third considers how we perceive audible properties. The third question in particular is related to the possibility that how we perceive audible qualities to be is not how these properties really are in the world. I shall, therefore, not answer the "how" question by means of the study of the psychophysical processes involved in auditory perception – i.e. the functioning of the acoustic apparatus we use in order to detect sound waves and transmit auditory stimuli to the brain – but by observing how audible qualities appear to us. Imagine, for example, that you are looking at the garden of your home through a window with yellow glass. You see the grass as yellow, but this does not mean that the grass is actually yellow. Therefore, in answering the question of how the grass looks to us, we might say that it looks yellow, even though the grass in the garden is not yellow.

The three questions just mentioned are closely related to each other. It seems that, indeed, in order for us to be able to answer the third question - namely, how we perceive the audible qualities of a given sound - we need to take the analysis of the medium into account, since we cannot say how the audible qualities appear to us in a vacuum, where they are not perceptible at all. Moreover, the analysis of the medium, in turn, is also necessary in order to answer the first question, which addresses the relationship between sound waves and audible qualities. I take into account here only the auditory perception of audible qualities, not the perception of them by

2 We distinguish the *event source* (jiggling, speaking, hammering) from the *thing source* (keys, mouth, hammer), and we identify sound with the event source by virtue of arguments against the mereological view (O'Callaghan 2011), according to which sound is part of the broad event of the sound source.

means of other senses. Of course, we can imagine a case in which we can perceive audible qualities in a vacuum by means of other senses in a very coarse-grained manner. For example, imagine a situation in which someone is playing the violin in a room where there is a vacuum. We could touch the neck of the violin and have a sort of perception of the audible qualities by "feeling" them. If you were to have a highly sophisticated sense of touch, you would be able to feel the vibrations of the sounding object- the neck of the violin - and eventually say whether the sound were loud or soft depending on the vibration rate you feel. We can thus say that we could perceive the sound's audible qualities in a vacuum.

At first sight, the second question regarding the relationship between audible qualities and sound sources might appear to be unrelated to the other two. In fact, it seems that we can answer the first question by saying that audible qualities are identical to the properties of sound waves without endorsing any account of the relationship between sound sources and audible qualities. At the same time, if we claim that the only object of audition is sound with its audible qualities (Warnock 1983), we can ask how we perceive audible qualities to be, regardless of their relationship to sound sources. On the contrary, if we look carefully we can note that the answer to the second question, regarding the relationship between sound and its source, will turn out to be relevant in addressing both the first and the third questions. Such relevance is based on two claims: 1) sound sources *determine* the properties of sound waves and, therefore, they determine the audible qualities as well (relating to the first question); 2) for audible qualities to carry information about the characteristics of sound sources, when we question how we perceive audible qualities to be, we might also question whether, at the same time, there is a way in which sound sources appear to us by virtue of the audible qualities they are related to (relating to the third question).

2. On the Relation Between Audible Qualities and Sound Wave Properties: A First Approximation

Audible qualities can be construed in two ways. In fact, in order to exist, they need their physical counterparts, namely sound wave features. At the same time, however, audible qualities are not fully reducible to their physical counterparts. Let us start with a discussion of the general issue regarding the relationship of audible qualities to wave aspects.

The feature of waves responsible for pitch is frequency. A higher pitch corresponds to a higher frequency, with higher frequencies heard as sharper sounds (an A6 sounds sharper then an A5). Analogously, lower pitches correspond to lower frequencies, as when we hear an E2 played by the fourth string of a double bass, which is perceived as a deep sound. The sound wave characteristic of intensity is responsible for the audible quality of loudness. That is, an increase in intensity corresponds to an increase in loudness, resulting in a louder sound. On the contrary, when intensity decreases, we hear a lower sound, of a lower volume, such as that of a whisper or of a violin played with a dumper. We can affirm that the same thing happens in the case of the perceptual quality of timbre,[3] where changes in the spectrum shape – which is determined by the partials[4] of sound – correspond to the sound's quality, which allows us to distinguish the sound of a piano from the sound of a violin.

Although audible qualities correspond to sound waves, they are not just perceptible counterparts of physical properties, but also appear to be causally determined by the properties of wave frequency, shape and intensity. As O'Callaghan (2007, 73) suggests, there could be different kinds of relations between audible qualities and their physical counterparts. For example, since frequencies are causally responsible for the experience of pitch, if we consider pitches as the physical properties that are causally responsible for experiences of pitch, then they are identical to frequencies. If pitches are simple or primitive properties of sounds, they can supervene upon frequencies (ibid, p. 74). If pitches are dispositions to create experiences of pitch, frequencies may still be considered as the categorical basis of such dispositional properties. Furthermore, I would add that, if we have cases in which pitches are experienced in the absence of frequencies, it is not true that experiences of pitch depend on frequencies.[5]

The same also applies to loudness. For instance, if we consider loudness as a physical property causally responsible for the experience of loudness, then loudness is identical to intensity. If loudness is a simple or primitive property of sounds, it can supervene upon intensities. If it is a disposition to create experiences of loudness, then intensities can be considered as the categorical basis of such dispositional properties. And the same argument could also be made for timbre.

Audible qualities, in order to be perceived, have to depend on properties ordinarily ascribed to sound waves, since audibility is assured by the

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3 The case of timbre is more complicated. It is controversial to give a satisfactory definition of it but, for the purpose of this paper, it will be sufficient to define it in a "negative" way: if two sounds have the same loudness, the same pitch and the same duration but they are heard as two different sounds, this dissimilarity can be explained in terms of timbre. For a discussion of timbre see Sethares (2005).

4 In section 4 there is an explanation of what the partials of sound are.

5 I refer here to cases such as the tinnitus, in which we hear a sound as having a pitch which could be more or less definite and which is generated in the absence of frequencies which are external to the ears of the perceiver.

presence of sound waves. Given that the medium is a necessary condition for the existence of waves and, considering also that audible qualities depend on waves, the medium turns out to be the necessary means which makes audible qualities also audible. A sound, in order to be heard, requires a medium through which sound waves might propagate. Since waves propagate only through such a medium, we cannot have sound waves in a vacuum.

3. The Problem of Vacuum

Before going further with the discussion of pitch, we have to clarify how the notion of sound as event source fits with the notion of sound as the bearer of audible qualities. According to a particular version of the distal view, we might have sound in a vacuum since, considering sound to be the vibration of the source, we might perfectly imagine a vibration in a vacuum, as in the case of a tuning fork under an empty jar (Casati and Dokic 1994, p. 42; 2005, p. 27). It may seem contradictory to claim that we have sound in a vacuum and then claim that audible qualities exist only in the presence of a medium, since the medium is the condition required in order for us to perceive them. However, the question is: how is it possible for sound to occur in an empty jar, even if this sound cannot bear the audible qualities which, in order to exist, require a medium? Even if these qualities required a medium in order to be heard, this would not mean that sound does not exist in a vacuum. Indeed, sound does exist in a vacuum, since the event source or the vibration exist in a vacuum, even if they cannot be heard. What is important to highlight is the fact that audible qualities can be explained not only in terms of sound waves' properties but also in terms of vibration's properties. The notions of sound as the bearer of audible qualities and sound as the vibration of the thing source are not in contradiction. It is simply that the vibration of the sounding object, like sound waves in a medium, possesses physical properties such as frequency, amplitude and phase which correlate to sound waves' properties and which determine also the nature of the audible qualities. In the specific case of pitch, there is even an identity between the frequency of sound waves and the frequency of the vibration of the thing source.
The vibration of the object can be considered as a sound wave where the medium is the sounding object itself. The audible qualities we perceive sound to have correlate with the physical properties of the sounding object vibration. The medium, such as the air, simply reveals them; it ensures that the physical properties can reach the ear and can be perceived. Sound waves make the audible qualities audible.

We have to distinguish between the informational medium and the surrounding medium. The informational medium is the medium in which the vibration is generated, while the surrounding medium is the medium in which sound propagates. In a vacuum, we do not have the surrounding medium, but we still have the informational medium. (Casati and Dokic 2005, p. 17).

The general idea is that, if you were on the Moon with a friend of yours who starts to play the gong, you would not be able to hear the sound of the instrument or the noise of his walking and, therefore, you could not perceive the audible qualities of the sound; however, we can still say that the sound of the gong or the noise of your friend's walking are there anyway.

The case of pitch shows how an audible quality depends on the thing source, and specifically on two aspects of the thing source: the way in which the thing source is stimulated and the materials from which the thing source is made. Moreover, the example of pitch further demonstrates that frequency, before being a property of sound waves, is a property of the vibration of the source, which is also present in a vacuum. Therefore, we shall consider the audible quality of pitch as the property of both the vibration of the thing source and of sound waves. It is as if audible properties were already present in the thing source in the form of vibration's features, and only in a second moment do we recognize them as being properties of sound waves by virtue of a medium. Pitch exists in a vacuum, even if it is not audible. In addition, I hold that, even if sometimes the ear perceives pitches which do not have a sound wave counterpart, the pitches perceived are a means to obtain information about the sound sources which produced them.

4. Pitch

If we opened a handbook of acoustics, we would read that sound waves are generally characterized by three mathematical quantities: frequency, amplitude and phase (Sethares 2005). Frequency is the number of complete oscillations of an elastic body in one second. An A4 corresponds to the frequency of 440 Hz, i.e. to an oscillation of 440 times per second. We perceive frequency as the pitch of a sound. In order to give an account of pitch which is consistent with the distal view, I shall need to demonstrate that pitch depends on the vibration of the object, even though, in order to be perceived, pitch needs sound waves in a medium.

When we listen to a sound, we hear a group of frequencies at once. The vibration which has the slowest rate is called the fundamental frequency; the other frequencies are the overtones or partials. A cluster of overtones formed by harmonics is constituted by frequencies of integer multiples with respect to the fundamental. The frequencies which differ from the fundamental are called partials, whether they are multiple integers or not. It is quite easy to individuate the fundamental of a sound in the case of musical instruments, such as a violin or a piano, and thus to establish what its pitch is. For example, in the case of an A4 played by the second chord of a violin, we have the fundamental at 440Hz, and on this frequency is superimposed a determinate sequence of harmonics. The first three harmonics of the A4 are the A5 at 880Hz, the E6 at 1320Hz and the A6 at 1360Hz.

However, for more complex tones, such as jiggles, African percussions or chimes, pitch is substantially indefinite. For instance, in the case of unpitched percussion instruments, such as a timbal or a cimbal, we do not have a definite pitch. The same applies for the snare drum, an instrument in which we have a drum with a membrane stretched over it. This instrument is a drum head which (differently from a vibrating strings whose overtones are at multiple integers with respect to the fundamental) produces a sound containing overtones at irrational ratios with respect to the fundamental.

The frequency theory, according to which to an increase in frequency corresponds a rise in pitch and a decrease to a fall in pitch, explains not only the ordering of pitches, but also offers the basis for musical relations and intervals, both of which are based on ratios of frequencies. Therefore, an octave has a frequency ratio of 1:2, the fifth of 2:3 and the fourth of 3:4.

Nevertheless, even if wave frequency mirrors perceived pitch quite exhaustively and thus explained the dependency of pitch on frequency, the way in which the wave vibrates depends on the material and on the manner in which the source is stimulated. If we considered the strings of a violin, for example, we would see that the length, the tension and the density of the strings are responsible for frequency and that as the length of the strings changes, the frequency also changes. A long string, such as the E1 of a double bass, will have a low pitch, while the E5 of a violin will produce a higher tone in relation to this. A string with a lower tension will produce a lower sound than the same string with a higher tension. In fact, when a violin player tunes her violin, she needs to calibrate the tension of the strings by turning the pegs at the scroll. If the note is sharp, she will loosen the string by turning the peg down; whereas, if the note is flat, she will have to turn the peg down.

Finally, frequency could also be modified by variations in the density of the strings. A heavy string produces a low sound, while a light string of the same length and tension produces a high one. For example, in philological interpretations of baroque music, string instruments use gut strings instead of metal strings. Two strings, a metal A4 and a gut A4, of the same length but made of different materials, will have the same frequency only if the lighter one, namely the gut, is tightened more than the metal one.

Moreover, a wave's frequency depends not only on intensity, density and length, but also on the way in which the source is stimulated. Suppose you are playing the G on the forth string of a violin with a bow and that this G is perfectly tuned at 196 Hz. It happens that if you slide the bow on the string with too much pressure, the sound you hear will not be perfectly in tune and it will be slightly sharp. Or, suppose you are playing a clarinet or a recorder, it happens that, in a similar case to that of the violin, if you blow too much air in the instrument with an exaggerated pressure of your lips, the resulting sound may be out of tune. The vibration of the object has a frequency which is determined by the material constitution of the object and by the way in which the object is stimulated, but this frequency is also a property of the sound wave and it is by virtue of the latter that it becomes audible.

Pitch is a cue which allows us to recover some information on the source which produced it. For example, the simple fact that we recognize a sound as having a definite pitch allows us to draw the distinction between the sounds of musical instruments and environmental sounds. In fact, whereas in the first case we hear a clear pitch, in the second one, because of in-harmonic partials which compose the complex sound produced by environmental objects, we hear an indefinite pitch. Therefore, the idea is that when we are able to detect the exact pitch of a sound, it is because we are hearing a musical instrument; on the contrary, when we are not able to do so, it is because we are hearing an environmental sound. There are borderline cases, such as particular African percussions, where the pitch oscillates from a clear note to an indefinite one, so that we cannot say if they are musical instrument sounds proper or environmental sounds. These border line cases belong to a third category: the un-pitched percussion instruments category, which cannot be easily distinguished from the categories of musical instruments and environmental objects, just by hearing the pitch of a sound.

We can go a step further, stating that through pitch we can not only tell the difference between environmental sounds and instrumental sounds but, within the category of instrumental sounds, we can also find additional elements related to pitch which help us to obtain some more precise information on the sources. For example, when we discriminate between a high pitch and a low pitch, we can appropriately say what the instruments

involved in the production of these sounds are. Considering the specific extension of musical instruments, you might be able to say that if we heard a very high sound, say an A7, we could exclude the possibility that instruments such as the double bass or the bassoon could have produced it. At the same time, if we heard an A2, it is unlikely that a piccolo or a violin could have produced it, but it is more probable that the appropriate sources could have been a tuba or a bass clarinet.
I am not claiming that, merely through pitch, we could recognize the actual source, in its totality, of the sound we hear, rather, I claim that pitch is, at least, a way for us to discriminate between different source groups, i.e. environmental sounds, musical instrument sounds and un-pitched percussion instrument sounds. In order to acquire more elements of sound sources, we also need loudness and timbre.

Pitch is an audible quality determined by the frequency of sound waves. Both frequency and pitch depend on the mechanics and the constitution of the thing source. But since we can also attribute a frequency to the vibration of the source, we can say that pitch is already present in a vacuum, in which – even if we cannot have sound waves and, therefore, cannot hear pitch – we can still register the frequency of the vibration of the source. Pitch enables us to recover some information about the instruments which produced it. Finally, I did not answer to the third question I proposed at the beginning of the essay – namely, how we perceive the pitch be – since I leave the study of particular auditory effects (i.e. Tartini's third sound and the virtual pitch) – where it seems that how we perceive audible qualities to be is not how these properties really are in the world – for further investigation.

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