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Sound resonance in prehistoric times: A study of Paleolithic painted caves and rocks

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Caves have natural properties of resonance: some parts sound very well, the sound lasts for some seconds or gives several echoes, some other parts have a dull resonance or no resonance at all. It is extremely interesting to compare in a given cave the map of the most resonant locations with the map of the locations of the paintings: are there correlations between resonance and paintings? Many Palaeolithic caves in France have been studied, and for them the answer was remarkably positive; stated shortly: the more resonant the location, the more paintings or signs are situated in this location. Here some results are presented. Special considerations on the acoustical aspects of such studies are given. The problem of the pictures / resonance relationship in open spaces with prehistoric painted rocks is briefly considered.

1 Introduction

In a given space, acoustics are different in different parts of this space and, of course, in a location the acoustics depend on the shape of the location. For instance, in an underground cave the resonance in a large hall differs from the resonance in a tunnel or a recess. Moreover, the resonance depends also on the material quality of the ground, walls or vaulted ceiling, be it made of e.g. hard stone, earth or clay. This is a trivial statement of no interest because of its evidence and generality. But this evidence appears much more exciting in the case of prehistoric *painted* caves. Indeed, because of the paintings the following question naturally arises: is there a relationship between paintings and acoustics? More precisely: *is there a relation between the locations of the paintings and the resonant quality of these locations in the cave?*

Since 1983 many studies have been made in several caves marked in the Palaeolithic (30 000 – 15 000 B.C.) with paintings, engravings, signs; these studies have shown that the answer is highly positive. Stated shortly: most of the paintings are located in the most resonant locations of the caves (see [3, 4, 6, 8] and [7] where other studies on archaeoacoustics are mentioned).

Here are some significant examples. (a) In the well known cave of Niaux (Ariège, France) most of the remarkable paintings are situated in the remarkably resonant *Salon Noir* that sounds like a Romanesque chapel. (b) In the cave of Arcy-sur-Cure (Burgundy, France), in the part of the cave that show signs of a prehistoric human activity, the density of the paintings is proportional to the intensity of the resonance (measured e.g. by the number of echoes). (c) In all the caves some very resonant recesses or niches are particularly ornamented. (d) In Le Portel (Ariège) along the gallery Jammes the locations of paintings correspond exactly to the main antinodes and harmonics of the resonance [6, p.45]. (e) In a number of narrow tunnels, where one has to crawl, there are no paintings or signs, except *red marks* at the very location of the maximum of resonance of the tunnel. (f) Often, just in front of such a resonant tunnel, or in front of a sounding recess, whose resonance resounds in a big part of the cave, pictures are found, clearly in relation with the sounding tunnel or recess.

A systematic study of many caves gives evidence that these coincidences are not accidental, in particular in what concerns the red marks (example (e) above) the odds are very high because these marks are in precise correlation with the maxima of the resonance [7, p.79]. This shows the awareness of the tribes that decorated the caves to the quality of sound and to the effects of resonance. Actually in the progressive discovery of a cave in the darkness, *the sound of the voice and a fine perception of the resonance are needed* (see below (2.1) S*ound as sonar*).

Apart from their acoustical aspects, the results have many prehistoric, anthropological, cultural and musical consequences. They give the best evidence for the ritualistic meaning of the paintings and of the use of the adorned caves. Indeed rituals and celebrations are mainly based on singing and music, and why would the Palaeolithic tribes choose preferably resonant locations for painting if it were not for making sounds and singing in some kinds of ritual celebrations related with the pictures? While in the discovery of the cave, male voices are needed (see below) this does not exclude the contribution of women's voices in the rituals, where instruments were possibly also played. This was certainly the case in the famous cave of Isturitz (Pays Basque, France), where bone flutes have been found [1] in the most sounding hall decorated with a remarkable pillar of carved reindeer [6, p.54]. In September 2003 – for the 50th Jubilee of the cave celebrated as a Monument Historique (Historical Monument) – I gave there a half hour concert, mostly of sounds of the voice using the effects of the resonance in various parts of this great hall; at the end of the performance most of the listeners were crying because of the stunning beauty of the sound in the darkness illuminated only by some candles.

From the prehistoric, anthropological and cultural point of view, the examples above and the results can be commented extensively and there is a lot to reflect upon. In this paper, however, we are mostly concerned by the acoustical point of view. There are some aspects that appear in practice and theory of the study of resonance *in situ*, aspects that need to be discussed from the point of view of acoustics:

2.1 Sound as sonar and resonance as a landmark.

2.2 What sounds?

2.3 The notion of strong resonance. How to measure it.

2.4 More precise formulation of the results.

2.5 The notion of resonance extended.

2.1 Sound as sonar

When acting in a cave in conditions similar to the prehistoric ones, without electricity, most of the time only with small oil lamps giving a dull light or, even, in large halls, with a torch (which cannot be used in narrow tunnels or recesses), the surroundings a few meters ahead are almost completely dark. The question immediately occurs: where to and in what direction is it possible to go? Since sound reaches much farther than reduced light, especially in irregular surroundings, the only possibility and security is to explore the cave with the voice and its echoing effects. Indeed, the resonance answers and one can hear from *where* it answers, from *how far* is the answer, how strong or deep it is, how many different answers (echoes) there are. It is then natural to proceed in the direction of the best (strong or deep) resonance obtained. In some caves, as in Rouffignac

(Dordogne) or Arcy-sur-Cure, proceeding in this way, one is naturally lead to the paintings. When crawling in a narrow tunnel, even a small oil lamp is hard to handle, in such a case the use of the voice enhances security: a deep hole in the ground is revealed by its echoing and alarming answer. A trained ear – as it was for men living close to nature – works as a sonar, elementary though as it might be. As remarked in the example (e) above, in such narrow pipes red marks sometimes appear exactly at the maximum of resonance of the pipe: it shows the importance of this effect for those who explored the cave. Certainly they were not making a purely acoustical study of the cave, but while progressing and making sounds they would stop at such a very resonant place and mark it, as a *landmark*, for further exploration or yet in some ritual, possibly, a kind of initiation process, considering the intimacy with the ground, the earth, the darkness and the depth of the sound (at the point of resonance) while crawling in the narrow tunnel. Now, keeping in mind the general relationship between paintings (or other ornaments) and resonance, most of the paintings can also be viewed as landmarks for resonance; this gives a new dimension for acoustics that prehistory has revealed to us.

2.2 What sounds?

In exploring the cave, it is clear that only the voice can be used, not only in the case of, either, a quick or a difficult progression as in a narrow pipe, because in such cases it is out of the question to use an instrument, but also because the voice can immediately be adapted to various pitches or sounds needed to discover the resonance or echoes. The voice is used almost as in a dialog, the answer being given by different parts of the cave. For this exploration of resonance, a male voice is needed; because of its lower notes and possible power. However, in some recesses or niches, a humming is often sufficient. Usually in an interval of a fifth, whatever it be, of a male voice, the main tone of the resonance or a related strong harmonic, characteristic of the resonance, is easily found, just by singing the vowel *o* or, as indicated, an *m* in a simple humming. Sometimes, for small niches, a slight cranial vibration (on *mm* or *hm*) is sufficient because, when using the resonance, it is strongly amplified. The practice, after a little training, is easy; when the right pitch is found, the answer – by definition of resonance – is remarkable enough. To explore the cave in this way, a female voice is usually not suitable, especially in narrow spaces: higher sounds are quickly damped down. But as we have seen, in large sounding halls, high voices usually do sound very well. To conclude, we have to make a distinction between (i) sounds needed to explore the cave, i.e. functional sounds, and, whence the best sounding locations for rituals, paintings and worship are found, (ii) the sounds used for this purpose. For (i), male voices are needed, for (ii) all voices and instruments (drums, flutes, rhombuses) can be used.

2.3 The notion of strong resonance and how to measure it

When stating the main results, the words *most resonant* or *remarkable resonance*, have been used. This notion has to be clarified. When the sound of the voice is in resonance with a part of a cave, the effect of the resonance is obvious: the whole part and possibly a much bigger part of the cave answers and sounds strongly, much stronger than the sound made initially. Notwithstanding this obvious contrast in the intensity of the initial sound and the intensity of the resulting sound, I have heard acousticians deny the reality of this impressive difference under the argument that the initial and the resulting energies should be the same. The impression of a stronger resulting sound is due to the concentration of the energy on a frequency selected by the resonance and to the powerful stationary waves that appear. However, the process is certainly complex; concentrated energy on a frequency because of its power and greater homogeneity can produce various phenomena, e.g. of saturation, while any measurement becomes misleading. The author, although both musician and mathematician, is not an acoustician; there are certainly theoretical and practical problems to be clarified and settled. In my approach, to state the results more precisely, I introduced the notion of *strong resonance.* In such a resonance (i) the sound increases in the mean more than 10 Db (measured with a sonometer Aclan SDN 80F) - the increase is often up to 15 Db and can reach much more in a precise frequency, or (ii) the resonance lasts for more than 3 seconds, or (iii) the resonance and vibrations in the cave can be heard at more than, say, 25 m, or (iv) there are at least 5 echoes. This notion of strong resonance in some caves had to be extended (see item 2.5). However, a sonometer that indicates intensity in given frequencies and harmonic overtones would improve precision in this matter.

The acoustical studies were carried out *vocally* in the broadest sense: the sound vibrations of the body in the register from middle C1 to G3, reinforced with strong harmonics (overtones), produced by a special technique, and whistles up to G5; and *aurally* (using, however, a tuning fork based on A440 to help determine pitches). In practice, as observed above, an interval of a fifth is usually sufficient to find the resonance and, as indicated, there is no need for great intensity of sound, since in a place of resonance, the right sound is immediately amplified; it is the natural resonance of the cave that counts. It should be noted that human sound perception, aural or in the body that perceives vibrations, is of an unequalled precision and, together with a trained ear, permits an invaluable approach for this sort of work.

The vocal work is also indispensable if we consider that the study is *anthropological* and not just geophysical and acoustical. The use of the voice provides a subtle approach which makes possible a profound study from this anthropological point of view. For example, the use of the voice and even just a breath or the body vibration when exhaling strongly on *hm* with a low sound, can, in a recess, produce a sound that resemble a growl of a bison sounding down a whole gallery because of strong resonance; I have often experienced such a very impressive effect. These arguments about the precision of a trained ear and fine perception, the necessity of an anthropological approach close to the one that could have been used by Palaeolithic tribes, have convinced acousticians and of course musicians of the soundness of this method. However, some acousticians have tried to use a machine making a white noise of a large and dense set of frequencies produced at the same time, and then comparing the intensity and duration of the echoing frequencies [2]. But the inconvenience is that, in the case of a strong resonance, the easily occurring saturation effects may leave the answer completely

inconclusive. In some cases, where the resonance is obvious, the machine did not show anything at all. Moreover, the conditions of emission are too far from natural ones and even more from subtle ones to be sufficiently reliable.

2.4 More precise formulation of the results

With the notion of strong resonance introduced above and the corresponding notion of *resonant location* (one which has a strong resonance), it is possible to formulate the following principles:

Principle 1 – *Most pictures are located in, or in immediate proximity to, resonant locations*.

It must of course be borne in mind that a painting requires a suitable place (this is not necessary for a mere sign); *in immediate proximity* means a location either at a distance e.g. no more than 2 m in a long gallery of about 50 m or more (but at a smaller distance in shorter galleries), either a location exactly opposite to the strongly resonant one (as in example (f) above). The expression *most pictures* refers to an unavoidable statistical approach. In Niaux, the Principle 1 is verified to more than 80% (because most paintings are in the *Salon Noir*), and verified almost as high e.g. in Le Portel and Arcy-sur-Cure.

Naturally, it is possible also to make a more refined distinction in the quality of resonance by introducing three levels of increasing intensity of the resonance up to the strong one (see the map of Le Portel's cave in [8]). It is then possible to formulate

Principle 1' – *The density of paintings in a location is proportional to the intensity of the resonance in this location*.

Example (b) above illustrates this point: at Arcy-sur-Cure, in the most important part of the cave, the density of pictures is proportional to the number of echoes (from 2 to 7) [6, p.47].

Conversely, it is unreasonable to expect all the locations with good resonance to be painted, there are in general too many and some are unsuitable or inaccessible. An *ideal* resonant location is strongly resonant and suitable for pictures. This leads to the next statement.

Principle 2 – *Most ideal resonant locations are adorned with paintings or signs*.

Finally, we have, as illustrated by example (e) above,

Principle 3 – *Certain signs are accounted for only in relation to sound.*

These principles give a more precise understanding of the relationship between paintings (or other ornaments) and location of resonance in the cave.

2.5 The notion of resonance extended

In some caves, for a wider understanding of the paintings / sound relationship, it is necessary to extend the notion of resonance by introducing the sounds made by stalactites and draperies. For instance, in the Gallery Larribau at Isturitz – Oxocelhaya some pictures and engravings are situated in non resonant locations, but next to sounding draperies. Actually, sounding draperies and stalactites appear as musical instruments; it is far from being obvious but in some cases it can be shown that they were used as such [6, p.46]. Another possibility of extension of the needed notion of resonance is in the idea of a correlation of different locations by their resonance: a particular location may be not very resonant but is well heard in another location (and the reverse). Therefore, in some caves (Le Portel, Oxocelhaya) appears the notion of a *network* of resonances.

3 Painted rocks

Finally we come to the study of painted rocks (3000 – 1500 B.C.) in the open air. Some sites have been studied on the lakes in Finland [5, p.541-557] and in Provence (South France) [6, p.49-51]; in the United-States, S.Waller has initiated a study (see [9] and chapter 4 in *Archaeoacoustics* mentioned in [7]). The natural way of measurement is in the number and quality of echoes (some answer whole melodies); because of the immensity in the open air, the possible geological changes and because of weather conditions, the problems are much harder than in underground caves. The main difficulty is in comparing the resonance of different spaces: where is the best sounding location? Are pictures related to the really best sounding locations? Some of the studies, however, are very rewarding.

The voice was used from D2 to D3, with an open air powerful singing technique (around 90 Db at the source). At the lakes in Finland, three studies (out of four) have been quite positive. In Provence, at a cliff called *Pin de Simon* (Gemenos, Bouches-du-Rhône), the best resonance effects (4 – 5 echoes) are obtained where five of the eight major paintings are concentrated. In particular in front of a *human with open hands and fingers* facing the sky, one gets five echoes, the echo effect lasting up to 5 sec. At another cavity there, at night in complete silence and no wind, I obtained during 6 sec. up to 8 echoes reproducing short melodies; this remarkable sounding location related to pictures eventually revealed a previously unknown one. Still in Provence, at Mont Begot, in the Vallée des Merveilles, there are several areas where I discovered a conjunction of rich sound values and pictures. Two areas are really remarkable. First, the *Lac des Merveilles* with, next to it, a very large flat rock called the *Altar Stone*, covered with more than a thousand pictures. There, by the lake, the echo answers whole melodies and it is a pleasure to sing or play at this place; one can easily imagine celebrations using voice and horns. Very remarkable also is the upper area with very large flat rocks and, facing the sky, many pictures including a famous one of a *human figure* (or 'god') with *zigzag* (or 'lightening') hands. There, because of the dominant position of the rocks, the echoes come from mountains all around, creating an unreal magical impression.

Keeping in mind the great number of rock-art sites discovered in the last decades and still recently, this subject opens a vast area of research.

Conclusion

The evidence of a sound dimension of painted caves and

rocks appears now as an important subject in prehistoric and anthropological as well as in musical studies. We have now a knowledge of how rich, for the prehistoric tribes, was the relationship between sound and paintings, caves, earth, space, lakes, rocks and mountains, linking the Visible and Invisible worlds and how deep and alive sounds and resonance were for them.

References

[1] Buisson, D., Les flûtes paléolithiques d'Isturitz, *Bulletin de la Société Préhistorique Française*, 87/10-12, Paris, p.420-432 (1990).

[2] Dauvois, M. & Boutillon, X., Caractérisation acoustique des grottes ornées paléolithiques et de leurs lithophones naturels, in C. Homo-Lechner et al. eds, *La Pluridisciplinarité en Archéologie Musicale*, IVe Rencontres internationales d'archéologie musicale de l'ICTM, Saint-Germain-en-Laye, 1990, Paris, p.209-251 (1994).

[3] Reznikoff, I., Sur la dimension sonore des grottes à peinture du Paléolithique, *Comptes Rendus de l'Académie des Sciences*, 304, série II/3, Paris, p.153-156 (1987).

[4] Reznikoff, I., Sur la dimension sonore des grottes à peinture du Paléolithique (suite), *Comptes Rendus de l'Académie des Sciences*, 305, série II, Paris, p.307-310 (1987).

[5] Reznikoff, I., On the sound dimension of prehistoric painted caves and rocks, *Musical Signification: Essays on the Semiotic Theory and Analysis of Music*, E. Tarasti ed. (Approaches to Semiotics 121), New-York, p.541-557 (1995).

[6] Reznikoff, I., Prehistoric Paintings, Sound and Rocks in *Studien zur Musikarchäologie* III*: Papers from the 2nd International Symposium on Music Archaeology*, Monastery Michaelstein (Germany), 2000, E. Hickmann ed. (Orient-Archäologie 107), Berlin, Rahden, p.39-56 (2002).

[7] Reznikoff, I., The evidence of the use of sound resonance from Palaeolithic to Medieval Times, *Archaeoacoustics*, C.Scarre & G.Lawson ed., University of Cambridge, Cambridge, 77-84 (2006).

[8] Reznikoff, I. & Dauvois, M., La dimension sonore des grottes ornées, *Bulletin de la Société Préhistorique Française*, 85/8, Paris, p.238-246 (1988).

[9] Waller, S., Sound reflection as an explanation for the content and context of rock art, *Rock Art Research* 10, 2 (1993).