Acoustic effects at prehistoric landscapes: an archaeoacoustics analysis of rock art sites from Western Mediterranean

ICA 2019 AACHEN

PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Acoustic effects at prehistoric landscapes: an archaeoacoustics analysis of rock art sites from the Western Mediterranean

Margarita DÍAZ-ANDREU[1]; Angelo FARINA[2]; Enrico ARMELLONI[3]; Laura COLTOFEAN[4]; Mathieu PICAS[5]; Tommaso MATTIOLI[6]

[1] ICREA and University of Barcelona, Spain

[2] University of Parma, Italy

[3] AIDA S.R.L., Italy

[4,5,6] University of Barcelona, Spain

ABSTRACT

Many pre-state societies around the world give special importance to places where distinctive acoustic effects are generated. These places often receive special treatment including the production of rock paintings in them. In the Western Mediterranean, it seems that outstanding acoustic effects such as directional echoes, augmented audibility and long reverberation time are present in some rock art areas with Neolithic depictions made between the 7th and 4th millennia BC. These have been painted in different styles that have been given the name of Macroschematic, Levantine and Schematic rock art styles. On the basis of the results of our acoustic tests, we argue that there is a strong probability of acoustics having been used as a method by Neolithic artists to select the shelters in which to produce rock art. This paper presents the results of the ongoing ARTSOUNDSCAPES ERC Project on archaeoacoustics. This project seeks to explore the role of sound in the creation and use of rock art sites. he authors discuss the results of previous fieldwork in three countries (Spain, France and Italy) and the development of an innovative set of research methods that include 3D Ambisonic recordings, GIS soundshed analysis, and Transmission Loss measurements.

Keywords: Archaeoacoustics, Rock Art, Neolithic, Soundscape, Mediterranean

1. INTRODUCTION

In the last two decades archaeology has gone through a renewal in the analysis of the materials left behind by past communities. Archaeologists are looking beyond the materiality of the past and trying to recover other less evident and intangible cultural signs such as those related to the senses, including hearing. These studies are based on the hypothesis that sound may have been as important for the people of the past as other more tangible aspects traditionally considered by archaeologists. Our interdisciplinary group formed by members of the Universities of Barcelona (prehistoric archaeology) and Parma (acoustical engineering) have been collaborating since 2015 in order to test the soundscapes of rock art landscapes. The first such collaboration took place in the context of the Marie Curie SONART project and, since October 2018, it continues in the framework of the ERC

[1] m.diaz-andreu@ub.edu
[2] farina@unipr.it
[3] armelloni@aidasrl.it
[4] laura.coltofean@ub.edu
[5] mathieu.picas@hotmail.fr
[6] tmattioli@ub.edu

ARTSOUNDSCAPES project.

2. ECHOLOCATION AND THE PLACEMENT OF ROCK ART

Several studies in psychoacoustics have demonstrated that some people have the capacity to locate places and orientate themselves by identifying the exact location where echoes and sound reflections come from. This ability, usually observed among blind people - but also sighted people that have been trained- is called echolocation (2) (3: tables 1 and 2, 4). Was echolocation used in the past? In answering this question, one of the major difficulties that archaeologists are confronted with is that this activity does not need or leave any sort of material culture.

Figure 1 - Shelters 30 to 34 on the eastern side of Baume Brune (France). Only Shelter 3, the best sound reflecting surfaces of the cliff, has rock art (arboriform) (photo by the authors)

In the field of rock art, the absence of material evidence related to echolocation has led specialists to search for indirect proofs connecting echoes and rock art. A high correlation between rock art sites and places where echoes are produced has been mentioned by several archaeologists (5). In most cases this correlation is made subjectively, based on the appreciations of the auditory experiences that the researchers themselves have encountered at the sites (6-9). A more objective approach has recently been introduced by archaeologists Margarita Díaz-Andreu and Carlos Garcia Benito in Spain (10, 11) and by Riitta Rainio in Finland (12). Both teams have conducted their tests using procedures developed in the field of acoustical physics. It is in this line that the authors of this article, an interdisciplinary team of archaeologists and acoustic engineers, have been working for the last two years.

In 2015 our team developed a method to investigate the Direction of Arrival (DOA) of echoes and sound reflections. This method is a combination of 1^{st} Order Ambisonics recording technique and Spherical camera pictures, and it is adapted to fieldwork in open-air landscapes (13). We have developed a specific software (called IR-Spatial) to post-process the 3D Impulse Response (IR) and to calculate the values for the azimuth, elevation and sound intensity of the sound reflections reaching the listener. The software also creates a slow-motion video that enables us to "see" where the echoes and reverberations come from during fieldwork. With the resulting data we calculated the correspondence between the DOA of sound reflections and the positioning of rock art shelters in the landscape. This methodology allowed us to further approach the question of whether echolocation was used by prehistoric populations in the selection and use of rock art sites. This methodology has been applied in the Schematic rock art landscapes of Baume Brune (Vaucluse, France) and Valle d'Ividoro (Puglia, Italy) (fig. 1). In both these areas, of the many available rock shelters, our results indicate that only a few were chosen by artists at the end of the Neolithic, and that these shelters corresponded with those with the best sound reflecting surfaces of each region.

3. BEING HEARD AT DISTANCE: THE PROPAGATION OF SOUNDS FROM ROCK ART SITES

Ethnography and historical sources indicate that some rock art sites, especially those used as venues for different activities, such as ceremonies with dance, music and sounds, were expected to be audible at distance (14-17). In these places, the sound coming from rock art sites was used to inform the members of the community that the ritual in the decorated site had begun or finished. Blesser and

Salter use the term "acoustic arena" to refer to the area where listeners become part of an acoustic community, as they can hear the same sonic event (18:22). In the same way as everyone in a concert hall wants to listen to the same music, or everyone within earshot of a church bell may feel rooted within the same community, the people in the area around rock art sites might have been interested in hearing what was going on inside the decorated sites.

The concept of "acoustic arena" has important consequences: not only does it determine the maximum distance between a listener in the landscape and the source in the rock shelter, but it also defines the size of the rock art audience. The size of the acoustic arena can vary depending on the loudness of the signal and the ability of the place to propagate sound. The smaller the acoustic arena, the lesser and more private the audience. In this case great importance might be given to the negotiation about who should legitimately participate in this acoustic community. On the contrary, the broader the acoustic arena, the larger the audience. This implies a broader message for large gatherings of people.

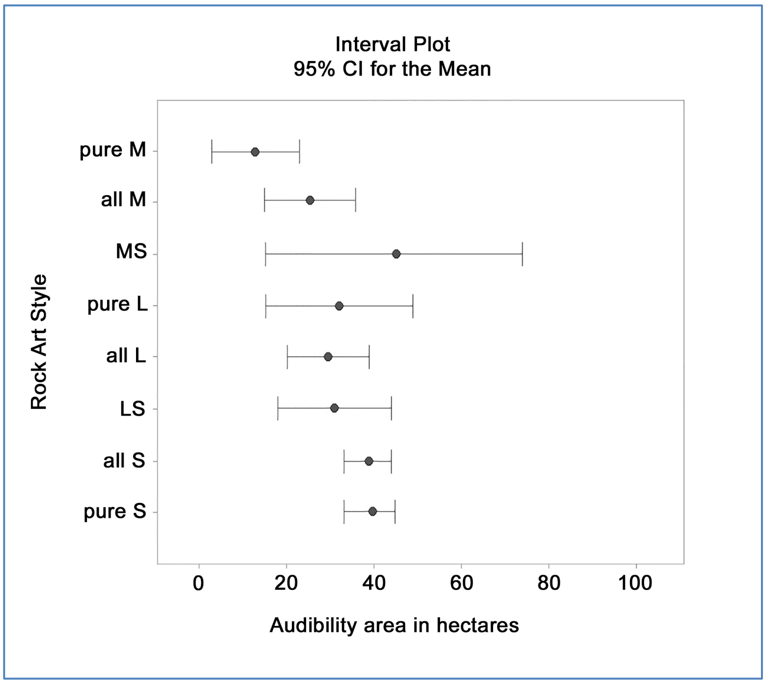

Figure 2 - Interval plot (central tendency and variability of the data) of the audibility of sound produced within rock art sites in hectares according to the type of art: Macroschematic (M), Macroschematic and Schematic (MS), Levantine (L), Levantine and Schematic (LS), and Schematic rock art styles (S). (from (1))

In our project we have investigated the propagation of sounds from rock art sites by modelling the so-called soundshed using SpreadGIS for ArcGis (1). In particular, we modelled the propagation of sound from a set of 128 rock art sites in the mountainous region of Alicante in Spain. This area is unique in the Mediterranean in that it contains three different post-Palaeolithic rock art styles, all of which co-existed during the Neolithic period (c. 5600-2800 cal BC) (19): the earliest Macroschematic motifs, and the somewhat later Schematic and Levantine styles. The chronological development and partial overlap of rock art traditions in this area allowed us to make comparisons between rock art styles in the search for patterns.

The data obtained from the soundshed analysis reveal interesting results (Fig. 2). Firstly, there is a clear difference in the propagation of sounds between Macroschematic rock art sites, on the one hand, and Schematic sites, on the other, with values ranging from 12-33 hectares (Macroschematic) to 33-44 hectares (Schematic). These results seem to indicate that when the first Neolithic artists, i.e. those painting Macroschematic motifs, decided to decorate the landscape, they were less interested in reaching large audiences than the later Schematic artists. Instead, the creators of the latter rock art tradition appear to have taken a great interest in audibility in the wider landscape. Secondly, a close inspection of sites with two or more styles leads to further insights. When the Schematic artists had to make decisions on where to paint, among all the previously painted Macroschematic sites they tended to choose only those that had higher audibility, thus revealing that acoustic perception was one of the major elements in the selection of sites to be decorated. The results appear to reflect the relative irrelevance of audibility for Levantine artists in the Mountains of Alicante.

4. HEARING DISTANT SOUNDS IN ROCK ART SITES

The ability of rock art sites to propagate sounds towards their surroundings has its counterpart in their ability to receive sounds coming from visually remote places. In this regard, it is not unusual to find anecdotal information in the literature about rock art sites at which sounds from the surrounding landscape can be remarkably well heard (20:123) (21:26) (22:10) (14:273) (10:3596). From an acoustical point of view, the audibility of sound sources placed at far distance from the listener depends mainly on the topography of places. Rocky landscapes full of hard vertical surfaces, as is the case of most of rock art landscapes, often have the potential to greatly enhance the auditory perception of distant sound sources. Canyon walls and vertical cliffs act like a set of curved or angled mirrors that bounce sound waves out and back at an unexpected distance, in a similar way to building façades in so-called "city canyons" (23). Interestingly, the use of the mirror as a metaphor to explain the propagation of sound beyond visual barriers was first mentioned by Greek and Latin authors (24:704). In addition, the augmented audibility of distant sounds in rocky landscapes can also be enhanced by the curved surfaces of the rock shelters themselves that allow impinging sound waves to be reflected and concentrated at a focal point, like a parabolic mirror. A listener standing at the focus point may experience louder sound levels than in adjacent positions (25:97-100).

Figure 3 – Baume Peinte rock art site. (photo Ph. Hameau)

How can we measure the auditory illusion of proximity to distant sound? How can we verify whether there is a positive connection between this auditory illusion and the placement of rock art? Within the framework of the SONART project, we were able to assess experimentally this relationship by applying the Transmission Loss (TL) analysis at two rock art areas, Baume Peinte (26) in France (fig. 3) and Arroyo de San Serván (27) in Spain. TL analysis allows the identification of the sound level reduction (or attenuation) in decibels (dB) of a sound signal propagated between two points: the sound source and the receiver (28:175). Given a sound source in the landscape and a receiver placed in a rock art shelter, we assumed that the lower the attenuation, the higher the sound level that would be perceived at the receiver position (shelter) and therefore the better the audibility of distant sounds. In order to allow better comparisons, both shelters with and without rock art were measured. In our field tests, we used a portable loudspeaker placed in the landscape playing a 90.7 dB sine-sweep signal ranging from 20 Hz to 20 kHz and an omnidirectional microphone connected to a digital recorder installed in the shelter. As a second step in our analysis we used TL analysis to compare the measured attenuation at the receiver (shelter) to the attenuation that would be expected based on geometrical sound propagation in a free space (-6 dB per doubling of source distance, see (29)). If the measured and predicted attenuation values are similar, it means that the rock art shelters are not different to other places in the landscape, i.e. that the audibility of distant sounds at the receiver (shelter) falls within the average range of audibility in the area. In contrast, if the measured attenuation at the receiver position (shelter) is below that expected, it means that the shelter possesses the ability to increase the audibility of distant sounds. The final stage of our analysis was to compare values from different shelters (both with and without rock art) to verify whether there was a pattern of association between shelters with rock art and the augmented audibility of distant sounds.

The data obtained from the two rock art areas provided significant results (Fig. 4). They indicate that, given the same sound source, the signal received at rock art sites was louder than that received at non-rock art shelters. In terms of perception of distant sounds, this means that non-decorated sites offer the same degree of audibility as most other places in the landscape, while decorated sites are exceptional in that they can amplify sounds coming from an external source. In summary, our results indicate that the shelters at the Baume Peinte and Arroyo de San Serván rock art areas were possibly selected because of their higher audibility values.

5. CONCLUSIONS

Archaeoacoustics – the archaeological study of how already disappeared societies made use of acoustics in the form of music and sounds – is bringing new light on the effect of the senses in the past. In this article we have shown that the results of acoustic tests made in rock art landscapes have revealed the importance of acoustic effects in the Central and Western Mediterranean during the Neolithic, a period in which the prehistoric communities of that area adopted agriculture in a long process covering the 7th to the 4th millennia BC. Our tests in sites in Italy, France and Spain point to the fact that there is a range of acoustic phenomena relevant for the people that inhabited each of the landscapes we have measured. Those discussed in this article are echoes and the ability to receive sounds coming from visually remote places. Yet, not all of them were present in the same location. The communities living in the landscape of Baume Brune (Vaucluse, France) and Valle d'Ividoro (Puglia, Italy) were sensitive to echoes, something we have been able to demonstrate thanks to the study of the Direction of Arrival (DOA) of echoes and sound reflections. Instead, those living in the mountainous area of Alicante liked being heard at a distance, but not to start with (when the earliest Macroschematic style was painted) but at a later time in a period between the Neolithic and the subsequent Chalcolithic (when Schematic rock art style became common). We have managed to prove this distinction by studying the "acoustic arena" or the soundshed using SpreadGIS for ArcGis. In contrast to these two areas in the Baume Peinte rock art site (also in Vaucluse, France) and in Arroyo de San Serván rock art landscape (Badajoz, Spain), a third distinctive acoustic effect was preferred at the time of choosing the sites to be painted: the ability of these rock shelters to receive sounds coming from visually remote places. We were able to discover this by undertaking the Transmission Loss (TL) analysis in which we compared, as in previous cases, sites with and without rock art. These results show that working in interdisciplinary teams – in our case archaeologists and acoustical engineers – brings new evidences about the importance of the intangible among prehistoric societies. Our tests reveal new aspects of the past that were considered to be beyond analysis.

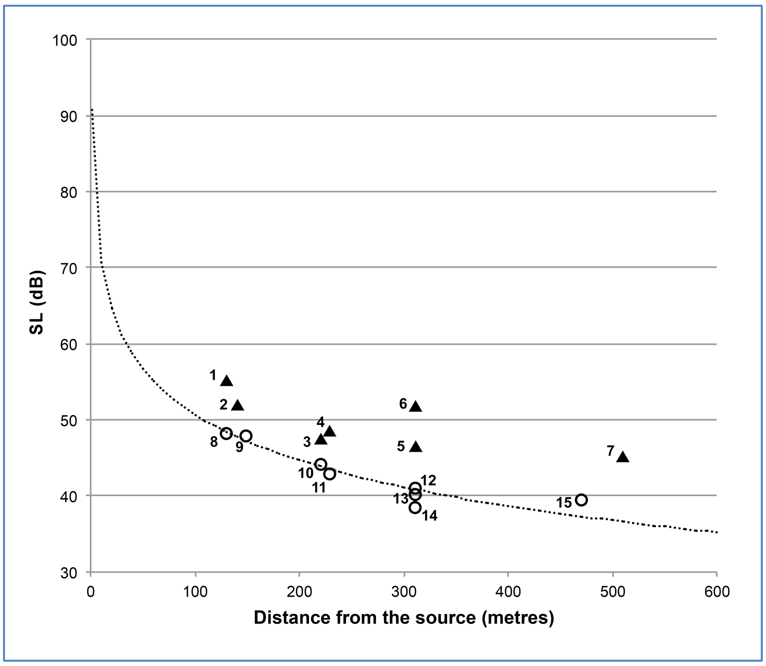

Figure 4 - Chart representing measured sound levels in shelters with rock art (triangle) and without rock art (circle) compared to predicted sound levels due to the geometric spreading of the sound signal (90.7 dB at 1 m) (dotted line) (1) Abrigo de La Sierra de San Serván; (2) Silletita del Rey; (3) Las Hogueras 2; (4) Las Hogueras 1; (5) Las Palomas 1; (6) Las Palomas 2; (7) Baume Peinte abri A; (8-14) Arroyo de San Serván rock shelters from S1 to S7; (15)

ACKNOWLEDGEMENTS

This article is a result of the ERC Artsoundscapes project (EC Grant agreement number: 787842).

REFERENCES

1. Díaz-Andreu M, García Atiénzar G, García Benito C, Mattioli T. Do you hear what I see? Analyzing visuality and audibility through alternative methods in the rock art landscape of the Alicante mountains. Journal of Anthropological Research. 2017;73(2):181-213.

2. Kolarik AJ, Cirstea S, Pardhan S, Moore BCJ. A summary of research investigating echolocation abilities of blind and sighted humans. Hearing Research. 2014;310:60-8.

3. Teng S, Whitney D. The acuity of echolocation: Spatial resolution in the sighted compared to expert performance. Journal of Visual Impairment & Blindness 2011;105(1):20-32.

4. Tonelli A, Brayda L, Gori M. Depth echolocation task in novices sighted people. Perception. 2015;44(1):1-14.

5. Díaz-Andreu M, Mattioli T. Rock art, music and acoustics: a global overview. In: David B, McNiven I, editors. The Oxford Handbook of the Archaeology and Anthropology of Rock Art. Oxford: Oxford University Press; 2018. p. 503–28.

6. Steinbring J. Phenomenal attributes: site selection factors in rock art. Journal of American Indian Rock Art. 1992;17:102-13.

7. Reznikoff I. Prehistoric paintings, sound and rocks. In: Hickmann E, Kilmen AD, Eichman R, editors. Studien zur Musikarchäologie III: Papers from the 2nd International Symposium on Music Archaeology. Monastery Michaelstein (Germany): Orient-Archäologie Berlin, Rahden; 2002. p. 39-56.

8. Reznikoff I. On the Sound Related to Painted Caves and Rocks. In: Ikäheimo J, Salmi A-K, Äikäs T, editors. Sounds Like Theory XII Nordic Theoretical Archaeology Group Meeting; Oulu: The Archaeological Society of Finland; 2014. p. 101–9.

9. Allan S, Waller SJ. Echolocation of Rock Art: Using Sound to Search for Sacred Sites. American Indian Rock Art. 2009;36:103-7.

10. Díaz-Andreu M, Garcia Benito C. Acoustics and Levantine rock art: auditory perceptions in La Valltorta Gorge (Spain). Journal of Archaeological Science. 2012;39:3591-9.

11. Díaz-Andreu M, Garcia Benito C. The sound of rock art. The acoustics of the rock art of southern Andalusia (Spain). Oxford Journal of Archaeology. 2014;33(1):1-18.

12. Rainio R, Lahelma A, Äikäs T, Lassfolk K, Okkonen J. Acoustic Measurements at the Rock Painting of Värikallio, Northern Finland. In: Eneix LC, Zubrow EBW, editors. Archaeoacoustics: The Archaeology of Sound Publication of Proceedings from the 2014 Conference in Malta: Paperback; 2014. p. 141-52.

13. Mattioli T, Farina A, Armelloni E, Hameau P, Díaz-Andreu M. Echoing landscapes: echolocation and the placement of rock art in the Central Mediterranean. Journal of Archaeological Science. 2017;83:12-25.

14. Boivin N, Brumm A, Lewis H, Robinson D, Korisettar R. Sensual, material, and technological understanding: exploring prehistoric soundscapes in south India. Journal of the Royal Anthropological Institute. 2007;13:267-94.

15. Rainbird P. Making sense of petroglyphs: the sound of rock-art. In: David B, Wilson M, editors. Inscribed Landscapes: Marking and Making Place. Honolulu: University of Hawai‘i Press; 2002. p. 93-103.

16. Williams GE, Patterson H. A Case of a Replica of a Musical Instrument (Rasp) at a Rock Art Site (5ME792) in Western Colorado. Southwestern Lore. 2013;79(2):1-12.

17. Vaughan JH. Rock paintings and rock gongs among the Marghi of Nigeria. Man. 1962;62:49-52.

18. Blesser B, Salter L-R. Spaces Speak, Are You Listening? Cambridge: MIT Press; 2007.

19. Martí Oliver B, Juan-Cabanilles J. Los primeros agricultores neolíticos mediterráneos (VI-V milenios a.C.) In: Almagro Gorbea M, editor. Protohistoria de la Península Ibérica: del Neolítico a la Romanización. Burgos:

Universidad de Burgos : Fundación Atapuerca; 2014. p. 19-41.
20. Hedges K. Places to see places to hear: rock art and features of the sacred landscape. In: Steinbring J, Watchman A, Faulstich P, Taçon PSC, editors. Time and Space Dating and spatial consideration in rock art research: AURA; 1993. p. 121-7.
21. Devereux P. The association of prehistoric rock-art and rock selection with acoustically significant landscape locations. In: Nash G, Children G, editors. The Archaeology of Semiotics and the Social Order of Things. 1833. Oxford: BAR International Series; 2008. p. 19-29.
22. Berrier M. Proposed Documentation and Storage of Data related to Acoustical Phenomena at Rock Art Sites. IRAC Proceedings American - Indian Rock Art 2000;26(1):7-18.
23. Kang J. Acoustics of long spaces. Theory and design guidance. London: Thomas Telford Publishing; 2002.
24. Koenen M. "Loca loquuntur." Lucretius' Explanation of the Echo and Other Acoustic Phenomena in "DRN. Mnemosyne. 2004;57(6):698-724.
25. Everest FA, Pohlmann KC. Master Handbook of Acoustics 5th ed. New York: McGraw-Hill 2009.
26. Hameau P. Les peintures schematiques de Baume Peinte (Saint-Saturnin-lès-Apt, Vaucluse, France) Zephyrus. 1997;50:179-97
27. Ortiz Macías M, Muñoz-Torrero Caballero E. Pinturas Rupestres Esquemáticas: escenas y composiciones. Arroyo de San Servan, Mérida y Zarza de Alange (Badajoz). Revista de Estudios Extremeños. 1990;XLVI:87-111.
28. Rossing TD. Handbook of acoustics: Springer 2007.
29. Embleton TFW. Tutorial on sound propagation outdoors. Journal of the Acoustical Society of America. 1996;100:31-48.