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Author(s): Juan José Ibáñez, Jesús Salas, Ignacio Clemente-Conte, and Narcís Soler

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Use and Sonority of a 23,000-Year-Old Bone Aerophone from Davant Pau Cave (NE of the Iberian Peninsula)

Juan José Ibáñez, Jesús Salius, Ignacio Clemente-Conte, and Narcís Soler

CSIC–Institución Milá y Fontanals (IMF), Departamento de Arqueología y Antropología, Barcelona, Egipcíacas, 15, 08001 Barcelona, Spain (Ibáñez and Clemente; ibanezjj@imf.csic.es)/Dept. de Prehistòria Universitat Autònoma de Barcelona, Edifici B, Facultat de Filosofia i Lletres 08193, Bellaterra, Barcelona, Spain (Salius)/Institut de Recerca Històrica, Universitat de Girona, Facultat de Lletres, Plaça Ferrater i Mora, 1, 17071 Girona, Catalonia, Spain (Soler). This paper was submitted 1 IV 14, accepted 11 X 14, and electronically published 24 II 15.

The production of sound is a significant human capacity that is used, through the generation of feelings and emotions, for conditioning social and biological reproduction. Despite this relevance and although several hundred instruments have been attributed to the production of sound along the Upper Paleolithic, our knowledge of how and in what contexts music was played during this period is still quite limited. In this paper, the aerophone found in the Davant Pau excavation, in the northeast part of the Iberian Peninsula, dated to 23,000 years cal BP, is studied to infer, through experimentation and microwear analysis, how it was made and used. It is a whistle-type instrument that would have allowed the production of an almost monotonic sound, which could be acutely syncopated, generating a fast rhythm. This is a type of sound most probably used in collective ceremonies in which the coordination of the participants was important, as observed in several ethnographic studies of hunter-gatherer groups.

Introduction

The production of sounds, through cognition and catharsis, is a powerful mechanism for promoting group identities and improving the strategies of collective coordination and synchronization (Brown 2000; Mithen 2005; Salius 2013). Though musical capacities were probably acquired very early in human evolution (Falk 2001; Honing and Ploeger 2012; Perlovsky 2012), in parallel to the origins of speech, the first direct proofs of the intentional generation of sounds appear at the beginning of the Upper Paleolithic in Europe. As the human manufacture of supposed instruments dated in the Middle Paleolithic has been ruled out (D'Errico et al. 1998),

the oldest known instruments are the flutes found at several sites in Swabia (Germany), dated around 40,000 years BP (Conard et al. 2009; Higham et al. 2012). The flutes from Isturitz (France), documented throughout the Upper Paleolithic sequence at the site (Buisson 1990:420–433; Lawson and d'Errico 2002:119–142), together with a few finds at other sites in Europe, have been identified as flutes/pipes owing to their morphology, similar to the modern instruments. Pierced phalanges interpreted as “phalangeal whistles” (Dauvois 1989), flat bone implements with a perforation at one end interpreted as bullroarers, and some pieces of bone with parallel grooves, which could have been used as rasps (Dauvois 2005), constitute the corpus of the putative Upper Paleolithic musical instruments (Morley 2003).¹

Microwear analysis and experimental studies can offer relevant data on the use of these first instruments. Microscopic examination of the surface of the supposed flute from Divje Babe I, dated in the Middle Paleolithic, showed that it was not made intentionally (D'Errico et al. 1998), while preliminary use-wear analysis on some of the flutes from Isturitz (D'Errico et al. 2003; Lawson and D'Errico 2002) and of the Hohle Fels flute (Conard et al. 2009) have offered some technical details on their elaboration and use. Additionally, some few studies have investigated the experimental reproduction of instruments, their use, and the analysis of the resulting sounds (Le Gouedic et al. 1996; Münzel et al. 2002; Zhang et al. 2004), exploring the sonic potentials of the instruments.

Despite the acknowledged importance of sound generation among hunter-gatherer communities (Morley 2013), our knowledge of this question during the Upper Paleolithic is very limited. The study on the use-wear marks and the sonority of putative musical instruments is a promising field of study on their technical characteristics and their social meaning. In this paper, a 23,000-year-old aerophone, found in the Davant Pau excavation, in the northeast part of the Iberian Peninsula, is studied to infer, through experimentation and microwear analysis, how it was made and used.

Materials and Methods

The Aerophone

The Davant Pau aerophone is a bone tube, 42.4 mm in length and 4.3 mm at its maximum diameter (fig. 1). At 15.5 mm from Extremity A and 24 mm from Extremity B, it displays a roughly square hole, 2.9 mm long and 3.14 mm wide. It was made from an ulna bone of a bird. The loss of the epiphyses of the bone during the manufacture makes it difficult to identify exactly the species the bone came from, but the number of candidates can be reduced to three: the jackdaw (*Corvus monedula*), the chough (*Pyrrhocorax pyrrhocorax*),

1. Their use as sound-producer instruments should be confirmed by microwear analysis

Figure 1. The Davant Pau aerophone. Pictures 1.1, 1.2, 1.4, 1.5 and 1.6 were taken through a Leica MZ 16A binocular microscope, while pictures 1.3, 1.7, and 1.8 were taken using a Leica DM 2500 M petrographic microscope. 1.1: Extremity A, showing the traces of bone sectioning, 20 magnification. 1.2: Section of Extremity A with traces of abrasion for regularizing the area, 72.5 magnification. 1.3: Section of Extremity A, traces of rubbing which have rounded and polished it, 200 magnification augmentations. 1.4: Central hole, 20 magnification. 1.5: Traces of scraping with a lithic tool to eliminate the protuberances of the feather insertions, 20 magnification. 1.6: Extremity B, 20 magnification. 1.7: Section of Extremity B, showing traces of polishing and striations, 200 magnification. 1.8: Traces in the surface of the tube in Extremity B, polishing and striations, 200 magnification. A color version of this figure is available online.

and the Alpine chough (*Pyrrhocorax graculus*) (Soler and García 1995). As the object has been dated in the Late Glacial Maximum, the coldest period of the Upper Paleolithic, it could have been made from a species adapted to cold weather, like the chough or the Alpine chough.

Context of the Discovery

The aerophone was discovered in “Davant Pau,” an archaeological excavation in Pau Cave, a prehistoric site in the Reclau complex (Serinyà, Catalonia, northeast Spain; Soler 1999; Soler et al. 2009).

J. M. Coromina made one test pit in 1974 in front of the entrance to a small site called Pau Cave, which was only a part of what was a much larger cavern, mostly collapsed. The sounding was called “Davant Pau,” which refers to this location in front of the cave. He excavated trench with a surface area of 6 m² and depth of 4 m, in artificial excavation units 20 cm deep. The upper units (1–13) correspond to post-Paleolithic times, units 14–16 (2.60–3 m) to the Late Solutrean, and units 16–19, from 3 to 3.80 m to the Middle Solutrean. Later and modern excavations made in the same levels south of Coromina’s pit confirmed this stratigraphy (Tarrús and Bosch 1990).

The aerophone was found in the deepest excavated unit, the 20th (from 3.80 m), which was abandoned before reaching 4 m depth. Because of its stratigraphical position under units 18 and 19, where some typical Solutrean tang points with flat retouch were found, and the presence in Unit 20 of two scrapers, one of them carinated, two blade cores and a burin, this unit can be attributed to the Middle Solutrean or to the Protosolutrean. Both are found in Reclau Viver Cave, only about 10 m north of the Davant Pau sounding (Soler 1986). Faunal remains with traces of human action are very abundant, especially of horse, bovid, and deer. A large fragment of bovid metatarsal, displaying a man-made fracture and butchery cuts from Unit 20, was dated by AMS to $19,320 \pm 70$ BP (Beta = 338590, $19,320 \pm 70$ BP, 2 Sigma calibration: Cal BP 23,340 to 22,900 and Cal BP 22,830 to 22,660).

Microwear and Sonority Analysis

Microwear analysis of prehistoric objects is based on the comparison, through microscopic observation of wear traces on experimental tools, whose use is known, with those present on archaeological objects (Clemente 1997; González and Ibáñez 1994). The aerophone was first subjected to a microscopic inspection through a Leica MZ 16A binocular microscope, at between 5 and 40 magnification and a Leica DM 2500 M metallographic microscope at 100 and 200 magnifications. Following the indications obtained in this first inspection, two similar objects were made. For this, two ulna of golden eagle (*Aquila chrysaetos*) were obtained, the diaphysis was cut, and the perforation was made with flint blades. The experimental objects were observed before and after manufacture and after use.

An acoustic analysis of the sound produced by the replica was carried out using an analog sonometer. The sound was recorded and the acoustic spectrum was analyzed, using Audacity software.

Results

Manufacture

The analysis of both extremities and the rectangular hole of the archaeological tube revealed multiple and continuous conchoidal scars (figs. 1.1, 1.4, 1.6), indicating that the ulna was cut with continuous small incisions using a pointed active zone. These conchoidal scars are typical of mineralized bones, when most of the collagen has been lost (Mozota 2012). This indicates that an important lapse of time had passed between the moment of the bird's death and the manufacture of the tube. A second line of incisions, which seems to be decorative, was also made about 1 mm from the extremity and parallel to it (figs. 1.1, 1.6). In the section of Extremity A, some striations can be observed (fig. 1.2). These were produced by rubbing this extremity against an abrasive stone, in order to regularize this area. The other extremity was not treated in this way and

therefore looks more irregular. The surface of the tube was scraped, so long parallel striations cover the surface of the object (fig. 2.1). These technological striations are composed of several strictly parallel furrows, which are caused by micro-chipping of the edge of a flint tool (fig. 3.3). The protuberances of the feather insertions were eliminated by scraping with a lithic tool (fig. 1.5).

Use

Manipulation of the bone tube with bare hands smooths the bone surface. When the hands are covered with dust or sediment, a condition that is reasonable to assume for Paleolithic users of the tube, manipulation results in the striation of the bone surface, and their direction shows the dominant movement of the hands/fingers. Polishing of the bone surface, which partially obliterates the long parallel striations resulting from scraping the bone surface, is observed all along the tube. However, most traces are concentrated around the perforation. This area is intensively striated in multiple directions (figs. 2.3, 2.4). Both extremities of the tube are intensively polished, and the ridges of the section of the tube are clearly rounded (figs. 1.3, 1.7). In Extremity B, some striations can be observed in the polished and rounded section of the tube (figs. 1.7, 1.8).

The analysis of the morphology of the tube and the use-wear traces allows us to infer its function and the way in which it was used. The tubular form of the object and the presence of a perforation strongly suggest that it was used as an aerophone by blowing in one extremity. Additionally, both extremities show intensive polishing and rounding. These polishing traces are consistent with the type of traces generated by repetitive contact with human skin. The area around the central aperture displays abrasive polish and abundant striations arranged in different directions. These traces, which we have replicated experimentally (figs. 3.4, 3.5), are consistent with rubbing the area with dirty hands, most probably due to the continual covering and uncovering of this opening in order to modulate the sound. The multiple directions of the striations—parallel, perpendicular, and oblique with respect to the axis of the tube—suggests that the finger moved in different directions, which may be the result of unnoticed small movements of the finger while playing the instrument.

In order to test these hypotheses, we attempted to play the replicas (fig. 3). The first trials, without placing any organic material inside the tube, produced no clear sound. Later, a block of wax was inserted inside the tube, near the central opening (fig. 3.1). With the addition of this plug or block, it proved to be straightforward to produce sound, blowing into one extremity with the other end of the aerophone covered with one finger, which caused a return of the air through the central opening (fig. 4), producing a continuous sound with an intensity between 85 and 90 dB, which could be modulated by covering the aperture. We have tried to play

Figure 2. Davant Pau aerophone. Pictures taken using a Leica DM 2500 M petrographic microscope, 100 magnification. 2.1: Striations interpreted as the result of scraping the bone surface with a lithic tool. 2.2: Extremity B. 2.3: Striations interpreted as the result of rubbing with the finger while covering and uncovering the central hole. 2.4: Idem. A color version of this figure is available online.

Figure 3. Experimental replica. Picture 3.1 was taken through a Leica MZ 16A binocular microscope at 20 augmentations, while pictures 3.2–3.5 were taken using a Leica DM 2500 M petrographic microscope at 100 magnification. 3.1: Central hole with a wax block inside. 3.2: Natural surface of the bone. 3.3: Striations from scraping the bone surface with a flint tool. 3.4: Multidirectional striations from rubbing the surface with the finger, in order to cover and uncover the central hole while playing the instrument. 3.5: Idem. A color version of this figure is available online.

the experimental replicas through both extremities and have obtained much better sonic results when the extremity nearer the sound window (Extremity A) was used as the mouth-piece. The thorough intentional smoothing of Extremity A would have produced more comfortable contact between the end of the tube and the lips. The striations observed in Extremity B would be the result of the obstruction of this end with the finger.

Sonority

The sonority analysis shows the frequencies emitted by the aerophone when played with the central aperture uncovered

(fig. 4). The principal frequency emitted by the replica of the aerophone when played in this way was measured at 3588 Hertz (A7). The aerophone produced a sound with an intensity of between 85 and 90 dB. The analysis revealed differences between the sounds produced when the replica was played continuously and with modulation of the sound. A very sharp cutoff is observed when the sound is modulated by blocking the central opening, either partially or completely. When the central opening is completely covered, the aerophone ceases to produce a sound, whereas by partially blocking about a third of the aperture, the pitch of the sound produced can be lowered by approximately a semitone. The aerophone could therefore be used to produce a continuous

Figure 4. Scheme showing the use of the aerophone and sonic spectrum generated when playing the instrument. A color version of this figure is available online.

high-pitched sound by playing it with the central opening uncovered, an intermittent sound by playing it while repeatedly covering and uncovering the aperture, or a slightly lower-pitched sound by playing it with the aperture partially covered.

Discussion

Flutes with multiple holes (up to five in the case of the best preserved Hohle Fels example), like those of the Swabian caves and Isturitz (French Basque country), appear in the Aurignacian period and are present all along the Upper Palaeolithic (Buisson 1990). These instruments produce a range of notes comparable to many modern kinds of flutes (Le Gondec et al. 1996; Münzel et al. 2002).

The Davant Pau aerophone belongs to the “block and duct” type of aerophone, where a block or “fipple” placed inside the

bone is designed to direct the breath toward a “sound window,” the central hole. In this way a vibrating air column is generated (Scothern 1992, cited in Morley 2003:56). This fipple would have been made with perishable material, such as wood, wax, or resin. A similar instrument was found in Goyet Cave (Otte 1979:410) in Belgium, attributed to the Gravettian period (Scothern 1992), though the chronology is not clear owing to the scarce precision of the old excavation. Another type of aerophone is represented by some bird-bone tubes with one buttonhole-like perforation near one of the extremities, which are present in some Magdalenian levels in cave sites in Cantabrian Spain and southwestern France (Menéndez and García 1998; Roussot 1970).

In the Davant Pau aerophone, the perforation in the body of the tube would not only have been used as a sound window, but was also used to syncopate the sound and modulate it

slightly. The possibility of syncopating the sound must have offered great rhythmic possibilities. The aerophone produced a sound with an intensity of between 85 and 90 dB, which might be audible from a distance of 100–200 m. This is a lower intensity than the sound that can be produced by a person whistling with just fingers and lips, which can reach a level of 130 dB at a distance of 1 m, and be audible as far as 10 km away (Meyer 2004). This makes it unlikely that the purpose of the Davant Pau aerophone was to communicate over distance. In addition to the relatively low intensity of the sound produced by the Davant Pau aerophone, the extent to which its sound may be modulated is quite limited. This range of possible modulations to the sound rules out the possibility that it might be used to imitate bird song or calls, and hence also the possibility that it might have been used as a hunting decoy.

Very often, aerophones are recovered in archaeological sites that show evidence of a large aggregation of people, such as Isturitz or Mas d'Azil (Bahn 1983; Morley 2009). This could have been also the case for Davant Pau during the Solutrean period, when intensive evidence of occupation in the cave system of Serinya is documented. Ethnographic evidence shows the consistent use of sound production in collective ceremonies (Morley 2013). In these contexts, the aerophone would have been used as a whistle to generate an almost monotonic sound, which could be acutely syncopated, generating a fast rhythm, while modulated music was produced with voices, as observed in several ethnographic examples among hunter-gatherer groups (Densmore 1918; McAllester 1996; Morley 2013).

Conclusion

About 23,000 years ago, a bird bone, collected some time after the bird had died, was chosen for making an aerophone. The two ends of the ulna were cut with flint tools, to make a tube in which a single hole was cut. The distance of this hole with respect to the mouthpiece was carefully calculated to produce an appropriate sound. The instrument was played by blowing into one end while the other was covered with a finger. The hole in the tube acted as a sound window, while a small ball of organic material (such as wax or resin) directed the air toward the window, producing a continuous sound with an intensity of between 85 and 90 dB. The hole not only acted as a sound window but also allowed the sound to be syncopated by covering it intermittently with a finger and to drop the sound by a semitone, by partially uncovering the hole.

The chronology of the instrument shows that besides flutes, which were already present in the Early Upper Paleolithic, whistles made in tube bird bones were used, at least, from the Early Solutrean.

In the Davant Pau aerophone, the limited intensity of the sound produced and the slight modulation that was possi-

ble suggest that the instrument was not used to communicate over long distances or as a hunting decoy. Instead, the instrument could easily create rhythms that might have formed part of collective ceremonies in which the rhythmic coordination of the participants was important, for example, when played simultaneously with other sources of sound (such as vocals or percussion), as documented in certain ethnographic contexts.

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