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Master and apprentice: Evidence for learning in palaeolithic portable art

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ABSTRACT

This paper presents the results of the statistical analysis of 280 pieces of Cantabrian and Pyrenean Middle Magdalenian portable art. Particular technical traces left on the medium by the act of engraving were identified through microscopic analysis and used to build a quantitative estimation of the overall technical aptitude of the engraver. Some traces considered as accidents or errors in the tracing were counted negatively, whereas others reflecting control of the tool and mastership in the use of various techniques were counted positively. A multivariate analysis based on this quantitative index, along with criteria including the type of medium was carried out using Correspondence Factor Analysis and completed with relevant statistical tests. The analysis clearly distinguishes three groups of pieces: those with a negative index, those that present a low positive index resulting from a balance between positive and negative traces, and those with a highly positive index.

These different categories of pieces may be tentatively assigned to different levels of experience in tool control and engraving techniques. The mean value of the technical index seems to be correlated with the type of medium and differs significantly in the various sites studied in the corpus. These data allow us to pose some hypotheses concerning the transmission of knowledge in Magdalenian societies, such as differential access to raw materials according to the engraver's experience, and different functionality of sites based on their production of decorated objects.

1. Introduction

Based on Mauss's ideas (1997), A. Leroi-Gourhan created the concept of "chaîne opératoire" that was subsequently applied to the study of lithic technology (Pelegrin et al., 1988; Pigeot, 1988; Karlin, 1991a, 1991b; Soressi and Geneste, 2011). The theoretical and methodological framework of the "chaîne opératoire" has focused on the study of the social meaning of the technical gestures intended for the production of various types of objects. Despite significant advances in the understanding of the technical actions, we are still far from interpreting the social and cultural factors underlying the technical gestures (Dobres and Hoffman, 1994). As pointed out by Mauss (1997: 363–86), the technique is an *effective traditional act*, which cannot exist without tradition and transmission. Therefore, the reconstruction of technical gestures is not only a way to determine the *know-how* of a society, but also reflects how this knowledge is perpetuated through learning systems and reproduces the cultural traditions of the society.

One of the most significant advances in this approach has been the identification of stages of learning in the creation of lithic tools (Pigeot, 1988, 1990). Numerous works have followed this line of research with the aim of understanding the mental processes involved in the making of lithic tools which could be related to the cognitive development of Palaeolithic people (Karlin, 1991a,b; Geribàs et al., 2010; Roux and David, 2005; Bril et al., 2010; Ellen, 2009; Aoki and Mesoudi, 2015).

In recent decades, numerous studies have applied this methodological framework to other elements of the archaeological record, such as bone industry or portable art (D'Errico, 1994; Fritz, 1999; Averbouh, 2000; Christensen, 1999; Dobres, 2000; Tosello, 2004; Farbstein, 2011). In the case of portable art, the study of operational chains for the production of decorated objects overcomes the limitations of traditional studies that consider the symbolic behaviour of Palaeolithic populations. The technical sequences used to create artworks obey rules that were learned and

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transmitted thus contributing to an understanding of the social and cultural significance of Palaeolithic art.

For instance, (in the case of engravings), the gestural sequences and the microscopic analysis of the technical traces, can identify, the products of artists with different levels of technical expertise (Fritz, 1999; Rivero, 2011). The reconstruction of the gestures of the engraver, analyzed from the technical parameters identified by comparison with experimental engravings, provides information on the degree of control of the tool and his/her interaction with the medium. The presence of certain errors and accidents linked to inexperience in the engraving allows us to establish different degrees of technical mastership. Therefore, it is possible to address issues concerning the transmission of graphics and technical codes involved in the production of artworks during the Upper Palaeolithic.

In Magdalenian art, transmission is confirmed by the persistence of technical patterns and conventions over long periods of time and vast areas (Rivero, 2015). Despite this evidence, and contrary to what happens in anthropology, very limited attention has been paid to the transfer of knowledge in prehistoric societies (Wendrich, 2013) and particularly in the case of Palaeolithic art. In this paper we present a study of portable art belonging to the Middle Magdalenian (14400-13300 BP, 17550-16250 cal. BP) from the Pyrenees and the Cantabrian Region in order to draw some hypotheses regarding artistic learning during the Upper Palaeolithic. The technical and statistical analyse allow us to consider different degrees of skill among Palaeolithic artists and their distribution in space.

2. Materials and methods

2.1. Corpus

Our study reconstructed the gestural sequences employed in the creation of 280 pieces of portable art (226 figurative and 56 non-figurative), made in both mineral (sandstone slabs, concretion stalagmite and pebbles of quartzite) and organic raw materials (bone, antler, tooth, ivory), from seven sites belonging to the Middle Magdalenian in Northern Spain and the French Pyrenees (Fig. 1). The Middle Magdalenian developed in parallel in both the Cantabrian Region and the Pyrenees and represents a moment of great cultural splendour, especially in the case of portable art.

We studied a sample of decorated objects recovered from some of the major caves of this period, in particular the sites of Las Caldas and La Garma in the Cantabrian Region (Corchón, 1995, 2004; Arias et al., 2011) and Isturitz and Le Mas d'Azil in the Northern slope of the Pyrenees (Table 1). Our corpus represents a small part of the total of decorated pieces (probably less than 40% for Isturitz and less than 10% for Le Mas d'Azil though no inventories are available). These sites were excavated during the first half of the 20th century and therefore offer a less precise archaeological context (Passemard, 1944; Saint-Périer, 1930, 1936; Breuil, 1902, 1903; Péquart and Péquart, 1960–1963). Nevertheless, the chronological framework of these sites is relatively homogeneous. Most of the C14 dates fall in the Bayesian limits of the Early and Late Middle Magdalenian (Barshay-Szmidt et al., 2016), with a high concentration in the Late Middle Magdalenian (Table 2). Events that took place during more than one millennium are not "contemporaneous", strictly speaking, but the actors belonged to the same culture and shared the same values for generations. Level II/E of the Grande Salle of Isturitz is probably a mixture of different cultural layers, as is shown by the presence of artefacts from the Early Middle Magdalenian and the Upper Magdalenian (Pétillon, 2004; Barshay-Szmidt et al., 2016).

Our corpus includes different types of engraved objects made in several materials and used for a range of purposes (Fig. 2). Pieces in organic materials include bone and antler industry or bone fragments without a known functionality (either due to an absence of use wear or fracture). Objects on mineral materials include slabs and pebbles, some of which were used as tools (compressor). Finally, perforated objects may be made of organic or mineral raw materials.

2.2. Technical analysis and methodology

Observation of the engravings by means of a stereoscopic microscope and SEM was used to determine the existence of a series of technical traces that indicate the level of motor control of the gestures by the artist. To be able to recognize and characterize the traces observed on the archaeological pieces, experimental engravings have also been studied (Rivero, 2011, 2015). Various types of incisions (linear, non figurative and figurative) were engraved on different types of materials (bone, antler, quartzite, sandstone), with a range of tools (flint blade or burins). The microscopic examination of the traces left on the raw material helped to distinguish the kinds of difficulties encountered by the engraver and the types of accidents that can occur.

Five types of traces have been recognized as marking inexperience, and six indicating experience (Fig. 3).

Marks indicating inexperience:

- Difficulty in deepening a single line. In order to deepen an incision, it is necessary to repeat moving the tool, between 1 and 6 times depending on the manual force of the artist and the hardness of the medium (Fritz, 1999; Rivero, 2012). These successive actions may be highly variable depending on the skill of the engraver. Inexperienced craftsmen are unable to continually maintain the tool in a single line as a result of a lack of control of the gesture (Fig. 3: a). Indeed, such a technical error is easy to distinguish from a stylistic effect called "multiple tracing".
- Tool escaping. During the deepening of an incision by repetition of the same gesture, the tool can escape from the main groove. This mainly occurs when the motif is small, and the hand and the tool hamper visibility (Fig. 3: b).
- Another result of the lack of control of the exerted force on the tool is the presence of involuntary "hookings" into the tracing, which appear as sudden changes of direction or small elevations in the interior of the incisions. They are especially frequent in the case of curved incisions, but beginners may have difficulties also in the case of straight lines (Fig. 3: d).
- Stick-slip oscillations are alterations produced at the bottom of a line as a result of the variation in pressure and are very common in curved incisions with an asymmetrical V-profile. This type of mark is identified by small transverse ripples and is often linked to a difficulty in motor control during the gesture (Fig. 3: c).
- Drawing correction. Corrections may be made on a motif or part of a motive, when the dimensions or proportions are not considered satisfactory. In these cases, the engraver modifies the line to rectify the error (Fig. 3: e). This trace is not exclusive to inexperienced engravers, but we have considered it as a negative index because it is frequently due to an involuntary deflection of the tracing.

Marks indicating experience:

In opposition to the previous traces, some technical aspects may be regarded as a proof of competence and skill in the handling of the tool.

Six types of technical traces indicating experience may be distinguished:

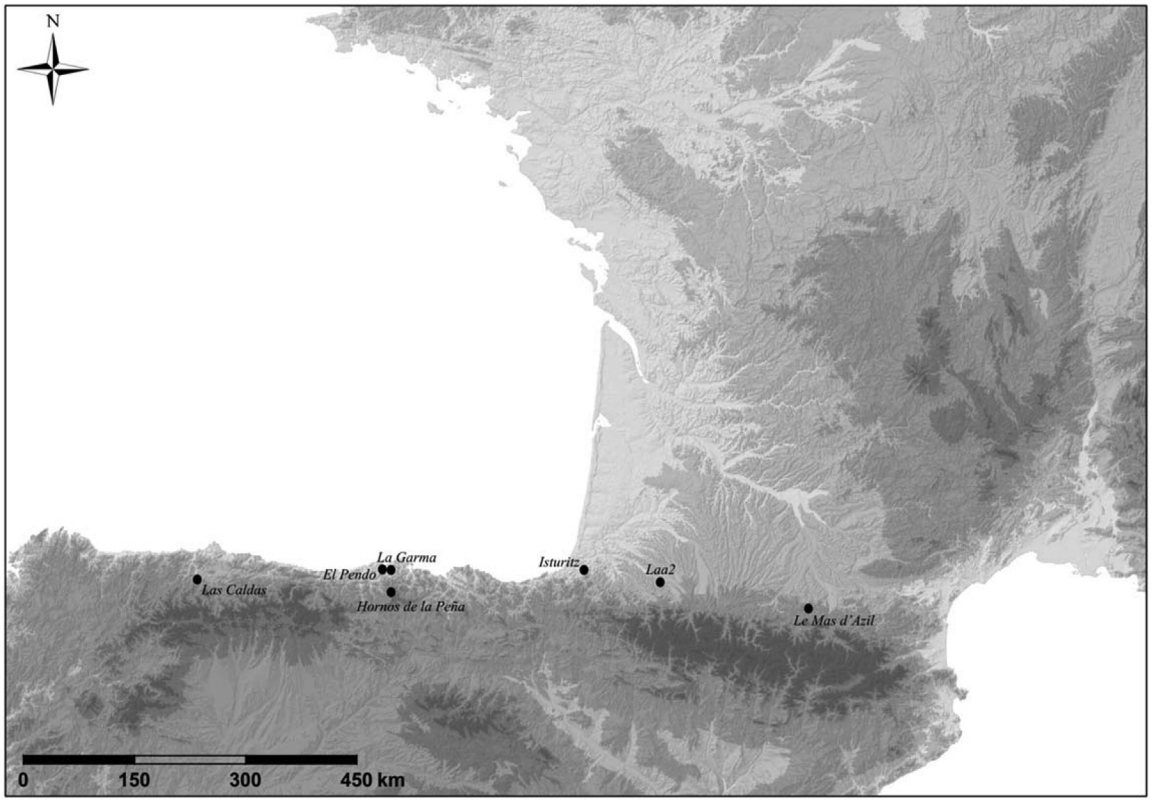

Fig. 1. Middle Magdalenian sites cited in the text.

Table 1
Number of artworks analyzed in the studied sites.

Las Caldas	El Pendo	La Garma	Hornos de la Peña	Isturitz	Laa 2	Le Mas d'Azil	Total
56	1	18	2	157	1	45	280

Table 2
C14 dates for the principal sequences included in the present study. EMM: Early Middle Magdalenian; LMM: Late Middie Magdalenian; EUM: Early Upper Magdalenian; LUM: Late Upper Magdalenian; MM: undetermined Middle Magdalenian.

Las Caldas	Level XI	Ua2734	13755 ± 120 BP	EMM	Corchón, 1999
Las Caldas	Level IX	Ua10188	13370 ± 110 BP	EMM	Corchón, 1999
Las Caldas	Level VIII	Ua10189	13640 ± 150 BP	EMM	Corchón, 1999
Las Caldas	Level VIII	Ly2936	13310 ± 200 BP	EMM	Corchón, 1999
Las Caldas	Level VIc	Ua10190	13650 ± 140 BP	EMM	Corchón, 1999
Las Caldas	Level IV	Ly2427	13400 ± 150 BP	LMM	Corchón, 1999
Las Caldas	Level III	Ua10191	13185 ± 155 BP	EUM	Corchón, 1999
La Garma Galería Inferior	Zone I	OxA8721	14050 ± 110 BP	MM	Arias et al., 2000
La Garma Galería Inferior	Zone III	AA45585	13810 ± 160 BP	MM	Arias et al., 2000
La Garma Galería Inferior	Zone IV	AA45581	13410 ± 120 BP	MM	Arias et al., 2000
La Garma Galería Inferior	Zone IV	OxA8722	13610 ± 100 BP	MM	Arias et al., 2000
La Garma Galería Inferior	Zone IV	AA78249	13714 ± 71 BP	MM	Arias et al., 2000
Isturitz	Level S1/Eω	OxA19832	14075 ± 60 BP	MM	Szmidt et al., 2009
Isturitz	Level S1/Eω	OxA19831	14110 ± 60 BP	MM	Szmidt et al., 2009
Isturitz	Level S1/Eω	OxA19830	13910 ± 70 BP	MM	Szmidt et al., 2009
Isturitz	Level II/E	OxA19836	15130 ± 110 BP	EMM	Szmidt et al., 2009
Isturitz	Level II/E	OxA19838	13605 ± 65 BP	MM	Szmidt et al., 2009
Isturitz	Level II/E	OxA19837	12245 ± 60 BP	LUM?	Szmidt et al., 2009
Isturitz	Level E	OxA-28083	15020 ± 70 BP	EMM	Barshay-Szmidt et al., 2016
Isturitz	Level E	OxA-28084	14605 ± 70 BP	EMM	Barshay-Szmidt et al., 2016
Isturitz	IstGD#1	OxA-26679	13980 ± 65 BP	LMM	Barshay-Szmidt et al., 2016
Isturitz	IstGD#4	OxA-X-2503-23	14005 ± 65 BP	LMM	Barshay-Szmidt et al., 2016
Le Mas d'Azil-Galerie des Silex	Ex 1940	Gif5680	13200 ± 100 BP	MM	Jaubert, 1995
Le Mas d'Azil-Galerie des Silex	Ex 1960	Gif5522	13640 ± 110 BP	MM	Jaubert, 1995

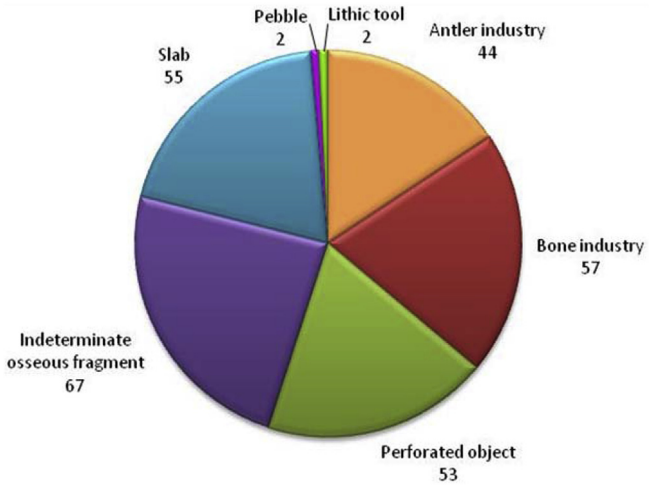

Fig. 2. Different types of supports analyzed in the present study.

- Incision depth. In which an incision has been repeated more than 2 or 3 times with an exact overlapping profile and without tool escape (Fig. 3: f).
- Profile combination. This criterion acknowledges the presence of different profiles of incision in the same figure for aesthetic reasons (V-profile, left or right asymmetrical V, straight angle, flat profile, W-profile). This shows that the contact between the tool tip and the support and the angle of attack are perfectly controlled (Fig. 3: g).
- Differential relief. This is a technique of great complexity that requires a very precise knowledge of engraving procedures. It consists in progressively lowering the external edge of an incision to create different visual planes in the case of overlapping figures or different parts of a single figure (Delporte, 1988) (Fig. 3: k). The visual effect is the impression of a realistic perspective, but here we only consider the technical difficulty that the author has to control.
- Combination of techniques. Mixing different techniques are mixed in the same object, such as engraving, carving, cutting of the medium or perforation is an indication of a skilled artist (Fig. 3: j). However, we cannot exclude the possibility that the various types of engravings were made by different authors.
- Precision of the gesture. This criterion notes the capacity to make short parallel incisions on the millimetre scale (between 1 mm and 200 μm) without varying the profile of the incisions, their depths, nor the distance between them (Fig. 3: h).
- Preparation of the surface. Experienced engravers generally prepare the surface of the support to level roughness (Fig. 3: i).

It should be noted that these six criteria indicate a highly skilled engraver. However, their absence does not mean that the engraver lacks experience. For instance, the absence of profile combination may result from an aesthetic choice and the absence of surface preparation may be a technical choice.

2.3. Quantification and data analysis

The identified traces (or "stigmas") of experience and inexperience on 280 pieces were recorded in a database (Livecode©). Using positive scores for experience and negative scores for novices, a technical quality index ranging between −10 and +10 was constructed and applied to each artifact (Table 3).

For the sake of the analysis, the quantitative "quality index" was discretized, i.e. converted into three qualitative values: negative (≤-1), low (0–3) or high (≥4) based on the existence of three groups clearly marked by inflections in the cumulative diagram (Fig. 4).

Correspondence Factor Analysis (CFA) (Benzécri and Benzécri, 1984) was particularly useful for the analysis of the scores. The selected attributes are the figurative or non-figurative nature of the represented motif, the nature of the raw material with 7 values as shown in Fig. 2, and the 3 qualitative values of the "technical quality index" (Table 4).

The provenance of every object was added in the CFA in order to distinguish the contribution of each site, but was introduced as "*supplementary elements*" (SE), so that it did not contribute to the axes of inertia.

The complete disjunctive table of presence/absence (280 objects x 17 criteria) was transformed into a generalized contingency table or *Burt table*, a symmetric table (17 × 17) that crosses all the parameters in the disjunctive table. At the crossing of line I and column J is the number of times criterion I is found associated with criterion J. The intersection of line I with column I is the total number of occurrences of criterion I. This type of table is particularly appropriate to reveal the correlation between criteria, although the information relative to the objects themselves is lost.

CFA analysis treats the *n* properties of each object as the coordinates of a point in a space of *n* dimensions. The method consists of determining the axes of inertia of this cloud of points and then projects the points in the planes constituted by the main axes of inertia.

The advantages provided by this method of analysis are multiple. The objects that look alike are located near to each other, while those that differ are separated. By virtue of the principle of duality between objects and properties, the two series of points are correlated and may be placed in the same graph. Objects and properties that are frequently associated are close together and two properties are close if they appear often associated to a single individual (Rivero and Sauvet, 2014). This method was complemented with Ascending Hierarchical Clustering (AHC) that allows a progressive grouping of elements in classes based on a measure of "affinity" or proximity. The result is a treelike hierarchical classification or *dendrogram*. On the other hand, the correlation between the criteria was analyzed using the Z-test (Chenorkian, 1996). Only probabilities higher than 90% were retained as significant in the discussion.

3. Results

Fig. 4 shows that the 280 objects can be separated into three groups based on the values of the "quality index" for each object: a group characterized by the predominance of a negative index (*neg*), consisting of 37 objects; an intermediate level (*low*) (indices between 0 and 3), corresponding to 84 objects, and a high level (*high*), with values of ≥4 in the index of quality, formed by 159 items. In a first approach, we can consider that engravers with different levels of technical expertise made the three groups of objects.

Knowing the "quality index" of each object, we have calculated the average value of this index for each site. Isturitz has the rank of 4.10, closely followed by Mas d'Azil (4.00). La Garma is a little lower (2.39) and Las Caldas does not exceed 0.57. Thus the "quality index" is a good means to evaluate the technical level globally achieved in the various sites. It is noteworthy that Isturitz and Le Mas d'Azil are not only the sites with the highest "quality index", but also the sites with the most abundant production of artworks. Both aspects are probably correlated and linked to a specific function of the sites during the Middle Magdalenian.

The histogram of the "quality index" presents an interesting situation (Fig. 5). At Isturitz, a bimodal distribution may be

Fig. 3. Traces of inexperience and experience identified on Magdalenian engraved pieces. a) Difficulty in deepening a unique line. Las Caldas, 3708, 12x. b) Tool escaping. Las Caldas, 772, 20x. c) Stick-slip oscillations. Isturitz, MAN sn_1, 50x. d) Hooking in curved lines. Isturitz, MAN 84658, 10x. e) Correction in the drawing of an eye. Las Caldas, 1023, 7x. f) Incision depth: several exactly overlapping incisions. Isturitz, MAN 86721, 50x. g) Combination of different profiles. Isturitz, MAN 84753, 10x. h) Precision of the gesture. Isturitz, MAN 84732, 50x. i) Preparation of the surface by scraping. Las Caldas, 724, 25x. j) Combination of techniques; engraving, cutting of the support, perforation. La Garma, GI 1002. k) Differential relief. Isturitz, MAN 84744, 10x.

Table 3
Traces of experience or inexperience with possible values, so that the quantitative "technical quality index" may vary between −10 and +10.

Trace	values
Difficulty of deepening	0/-1/-2
Tool escaping	0/-1/-2
"hooking" (straight line)	0/-1
"hooking" (curved line)	0/-1/-2
Stick-slip oscillations	0/-1
Drawing correction	0/-1/-2
Exact deepening	0/+2
Combination of profiles	0/+2
Differential relief	0/+2
Combination of techniques	0/+2
Precision of gesture	0/+1
Preparation of support	0/+1

observed: 142 pieces have indices between 0 and 9, and only 15 pieces have negative indexes (notes < 0). The two groups of objects should probably be attributed to two groups of engravers with different intrinsic technical levels (Fig. 6).

The Correspondence Factor Analysis of a Burt table crossing the 17 criteria of Table 1 was used to determine how the "technical quality indexes" are distributed according to the types of media and the archaeological site. The projection in the factorial plane [1,2] and the associated AHC show two main groups clearly separated along axis 1 (Fig. 7).

On the right the criteria of inexperience and intermediate level (*neg* and *low*) are grouped, associated with figurative representations (*fig*), lithic materials (*slab, pbl, lit*), indeterminate bone fragments (*iof*) and the sites of Las Caldas and La Garma. On the left side, we find the sites of Isturitz and Mas d'Azil associated with the

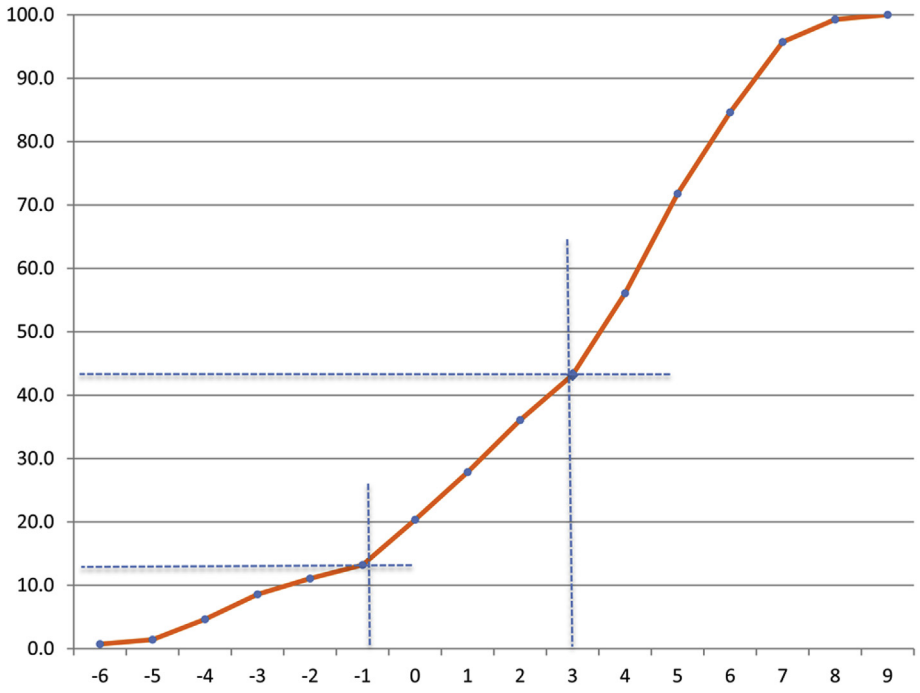

Fig. 4. Discretization of the technical index varying between −6 and +9 into three qualitative categories: negative: ≤−1; low: 0–3; high: ≥ 4.

Table 4
Coding of the criteria used in the statistical analysis.

Categories	Code
Figurative	*fig*
Not figurative	*nofig*
Antler industry	*ant*
Bone industry	*bone*
Perforated object	*perf*
Indeterminate osseous fragment	*iof*
Slab	*slab*
Pebble	*pbl*
Lithic tool	*lit*
Negative technical index	*neg*
Low technical index	*low*
High technical index	*high*
Caldas (Asturias, Spain)	*Cld*
Garma (Cantabria, Spain)	*Ga*
Isturitz (Pyrenees-Atlantiques, France)	*Ist*
Mas d'Azil (Ariege, France)	*Mas*
Other sites (Pendo, Hornos de la Peña and Laa2)	*Oth*

index of experience (*high*), bone and antler industry, perforated objects and non-figurative representations. The small sites gathered under the name of "other" (El Pendo, Hornos de la Peña and Laa2) appear in this group but the number of pieces is too small to be significant.

A Z-test was used to determine the probability that co-occurrence for each pair of attributes is not due to sampling variability. This is achieved by comparing the number of each co-occurrence of attributes with the theoretical number in case of a random distribution through the calculation of the reduced deviation Z. A table of Z values gives the probability that the null hypothesis can be accepted (Chenorkian, 1996: 27–29, see also http://www.socscistatistics.com/tests/ztest/). Only probabilities above 90% are taken into account to consider that the deviation is not due to sampling fluctuations (Table 5).

The three groups of objects differentiated by their "technical quality index" (Fig. 4) and also differentiated by CFA though negative and low indexes appear in the same class of the AHC. This supports the interpretation that the authors of the three types of

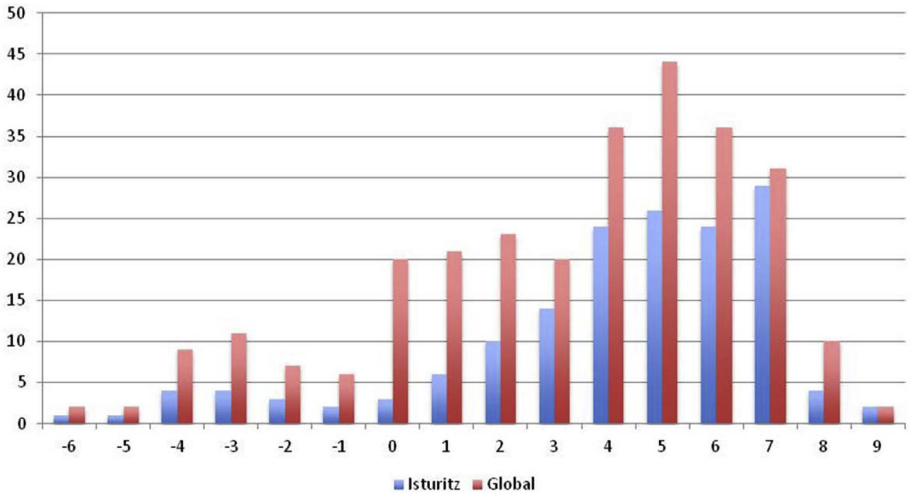

Fig. 5. Histogram of the "technical quality index" for the 280 pieces analyzed in this work, compared with the distribution of the objects from Isturitz.

pieces are engravers of different technical levels. These differences may correspond to three major categories: beginners, engravers in an intermediate stage, and experienced engravers.

In addition, CFA shows that these classes of engravers are associated with criteria like the types of materials they use and the function of the objects they produce. Thus, we can synthesize the information given by CFA in the following way. The studied corpus contains objects made by engravers that have not acquired a good control of the tool and should be considered as lacking in experience. They preferentially make engravings on indeterminate bone fragments without known function (*iof*). The correlation between this type of support and a negative technical index (*neg*) is significant (98% probability that it is not due to sampling fluctuation) (Fig. 8).

A second group of engravers, which could be considered of intermediate level, appear to have a strong correlation with lithic materials: slabs and pebbles. The correlation between a low quality index and slabs has a 98% probability to be statistically relevant and the correlation with the site of Las Caldas is also highly significant (P = 97%) (Fig. 9). The fact that low quality indices are associated with lithic materials may be explained by the almost complete absence of complex techniques such as relief, cutting, perforation or the previous preparation of the surface in the case of these materials. The lesser elaboration has already been acknowledged in the case of Magdalenian portable art on stone from the Dordogne (Tosello, 2003: 495). It should be noted, however, that sculptures on stone (particularly abundant at Isturitz) are not considered because they require a complex *chaîne opératoire* (Croidieu, 2012).

Finally, a third group of engravers would correspond to a high level of experience. The correlation of a high "quality index" with functional objects on bone or antler has a 93% probability to be significant and the group appears strongly associated with the sites of Isturitz and Mas d'Azil (Figs. 5 and 6b).

The correlation between the type of materials and the technical skill of the engraver is clearly revealed by the average quality index of each material. The highest scores are found for industry on antler (6.1), personal ornaments (5.0) and industry on bone (4.4). As expected, bone fragments without an identified function are much lower with a score of 0.7.

4. Discussion

It clearly appears that engravers with different degrees of experience are not working with the same raw materials, as if access to certain categories of materials depended on the competence in tool control and the capacity to employ complex technologies. Skilled craftsmen concentrate their work on bone objects (such as *lissoirs*) and a large part of antler items, such as rods and spear throwers. Perforated objects for personal ornament, among which there are *contours découpés* and *rondelles*, are also mostly carried out by experts (41 of 53). On the contrary, it is noteworthy that engravers who present difficulties in the control of the tool preferably use indeterminate bone fragments, probably used as "training" materials.

The information provided by the site of Isturitz is worth highlighting because the number of analyzed pieces from this site (157) allows more reliable statistical conclusions. First, the large proportion of objects made by engravers with a high level of experience (109/157) and the strongly significant correlation between Isturitz and the high "quality index" (P = 92%) seems to be an archaeological reality, non-dependant on sampling. We have already pointed out elsewhere the prominent role played by Isturitz during the Magdalenian period. The serial production of very similar decorated objects and some technical and formal innovations may be considered as an indication that Isturitz acted as a centre of creation and diffusion of artistic works over a wide area (Rivero, 2014, 2015).

The role played by Isturitz as a disseminator of technical and formal traditions during the Magdalenian period is clearly shown by the dispersion of the models across space. This may be explained in different ways. It is possible that engravers came to Isturitz from remote areas to learn specific forms and techniques and later reproduced them elsewhere. The fact that objects of medium or low technical index similar to objects of a higher technical index from Isturitz are found at Laugerie-Basse (Dordogne) or Hornos de la Peña (Cantabria) can be interpreted in such a way (Rivero, 2015). This implies that distant sites were in the sphere of influence of Isturitz. On the other hand, the serial production of objects with broad amplitude of technical indexes (e.g. *lissoirs* with an engraved head of bison, *contours découpés*, *rondelles*) probably indicates that the objects were produced in situ by craftsmen with different levels of expertise (i.e. different stages of learning). These two possibilities are not exclusive.

Another argument in favour of learning may be found in the cave of La Garma (Cantabria). This site is exceptional because the archaeological deposit has remained intact since the Middle Magdalenian, which allows us to know the distribution of the objects in situ since the closure of the cave (Arias et al., 2011).

Fig. 6. Two examples of portable art of different quality from Isturitz. a) MAN 84790. Engraved horse on a jaw fragment, Technical Index: −4. b) MAN 86477. Head of bison on a perforated baton, Technical Index: +8.

However, preliminary data did not show a differential distribution of pieces of portable art according to their degree of technical accomplishment. The objects made by experienced engravers were found near those carried out by inexperienced ones in Zone IV of the cave. Nonetheless, there is a clear distinction in the raw materials used by each group: stone (mostly fragments of flowstone) in the case of inexperienced engravers, and organic materials (bone, antler, ivory) in the case of experts. We may hypothesize that the inexpert engravers were training on materials readily available in situ, such as flowstones used as paving in Zone IV. On the other hand, the objects decorated by experts are mainly functional objects probably related to the activities developed in this area. It is worth noting that both types of objects were finally lost or abandoned, sometimes broken.

The large amplitude of technical expertise in the production of decorated objects point to individuals at various stages of learning because the practice of engraving requires the acquisition of a large background of technical knowledge over an extended period of time. Unfortunately, the available data do not allow us to understand how the artistic learning was conceived by the Magdalenian society.

Learning is a mixture of observation, imitation and education, which constitutes the basic principles of a process of “enskilment” (Ingold, 2000: 37). The society has to organize learning and transmission in a stable and reproducible system (Tehrani and Riede, 2008). To explain the long-term maintenance of complex and difficult-to-master skills transferred from generation to generation, adults or experienced people must actively guide and control the learning activities of their children/apprentices, a mode of transmission that can be labelled ‘pedagogy’. According to Bourdieu, the learner is an actor of the process, not a passive receptor. “The child imitates not ‘models’, but other people's actions” (Bourdieu, 1977: 87) and progressively integrate the structural principles that underlie them. This is particularly true in the fields of flint knapping and the making of decorated objects, which require a complex mixture of conceptual and motor skills that take long to acquire.

Apprenticeship is probably the most important link in human societies (Sigaut, 2011: 207). Learning takes place in many domains of the social life and is itself creator of social ties. For Palaeolithic hunters-gatherers, the processing of flint tools was a vital activity that had to be learned and mastered by everybody (Pigeot, 1990, 2011). In Magdalenian societies, the decorated objects are present in almost every settlement and presumably held an important place in the daily life. Besides the technique of engraving, the novices had to learn the symbols conveyed by the graphic language they were acquiring. Thus learning appears as an instrument for socialization and social cohesion. In that sense, the creators of portable art have largely contributed to the cultural unification that was observed during the Middle Magdalenian in a vast area including the Cantabrian Region, the Pyrenees and the Perigord (Sauvet et al., 2014).

We have seen that some materials such as bone fragments or fragments of flowstones were reserved to “beginners” whereas only experts seemed entitled to work on antler and ivory probably considered as “noble” materials. This apparent hierarchy of raw materials seems to be a direct consequence of the recognized technical and artistic skill of some engravers. This shows that a social value was probably imparted to the technique of engraving and carving and therefore to the learning of this technique.

The aptitude of certain individuals to produce decorated objects was probably recognized within the group and socially valued. We may assume that a status of “master” and “apprentice” was more or less implicitly assigned to some persons. But data are lacking concerning the “student-teacher” relationship. Learning by observation and imitation was probably the basic rule, but a certain supervision or control on the part of the masters was necessary, in a similar way as it has been highlighted in the case of lithic industry (Pigeot, 1990, 2011; Grimm, 2000; Sterling, 2005). In some cases, lithic reffiting suggests that experts made “pedagogical demonstrations” (Takakura, 2013), but we did not find a similar indication in our analyses, i.e. examples in which an expert would have corrected a drawing initially made by a novice. The case is possible, but unprovable. We can only underline that about 20% of the engravings carried out on indeterminate bone fragments nevertheless reach a quality index corresponding to the category “experts”. We cannot exclude that these rare pieces made using an unusual material could be models specially drawn to the attention of apprentices to teach them the proper gestures.

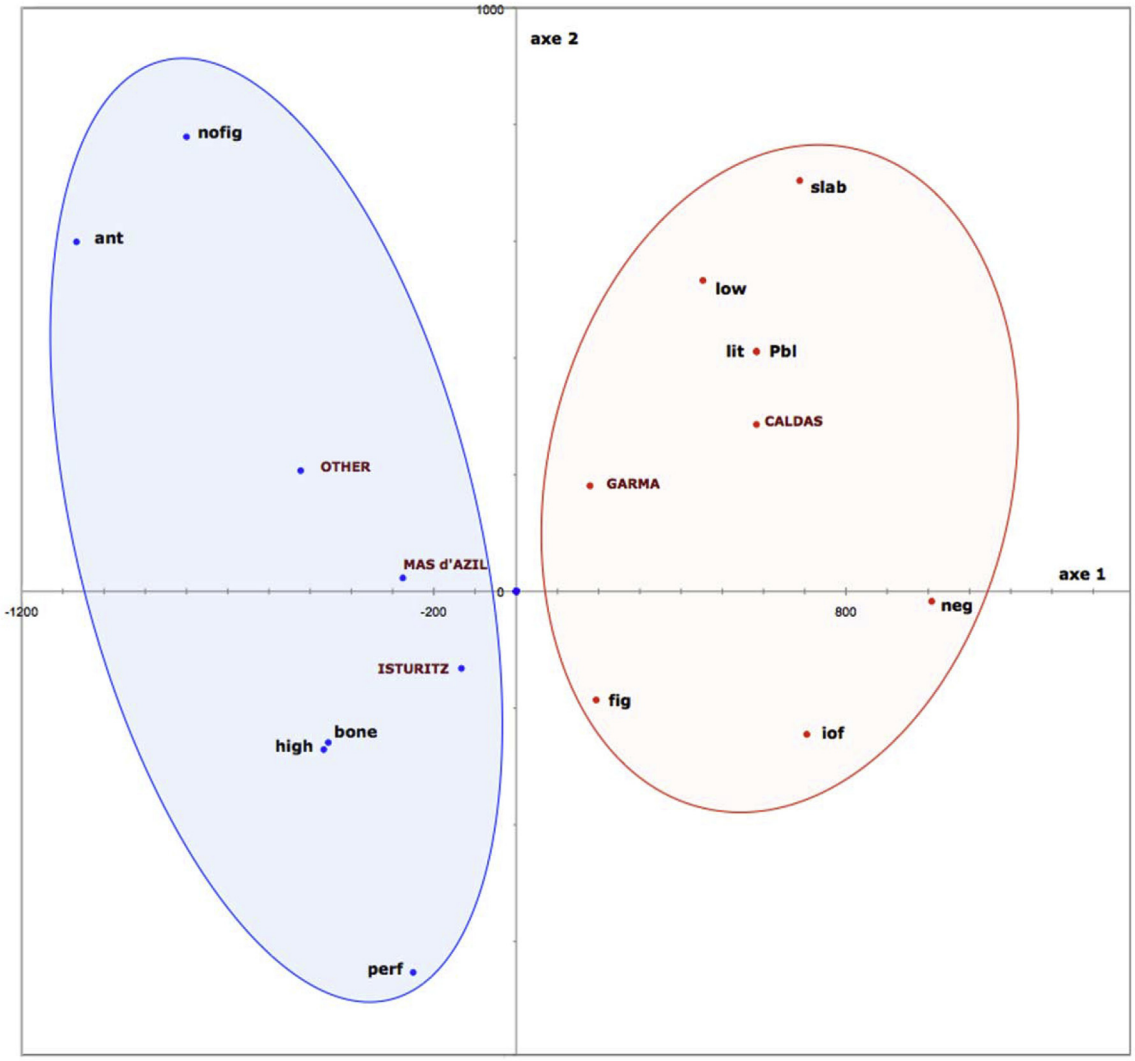

Fig. 7. CFA of a Burt Table of 17 × 17 criteria. Projection in the main factorial plane [1,2] representing 54% of the total inertia. The two coloured groups are the two main classes obtained by AHC.

Table 5
Z-test. Probability that the co-occurrence of two attributes is not due to the fluctuations of sampling.

Attributes	Negative index	low index	high index	Caldas	Isturitz
Indeterminate osseous fragment	98%				
Slab		98%			
Antler industry			93%		
Low quality index				97%	
High quality index					92%

5. Conclusions

The existence of engravers with different levels of technical expertise has been already observed, and the hypothesis of artistic learning in the Magdalenian societies has been proposed on the basis of qualitative observations (Fritz, 1999; Rivero, 2011, 2012, 2015). The methodology outlined in this paper aims at providing a more objective basis for these hypothese. A dozen technical traces left on bone or stone during the act of engraving were observed under the microscope, identified and used to establish a list of criteria allowing a quantitative estimation of the technical ability of the engraver. The study of a large set of Magdalenian portable art allowed the use of statistical tools such as Correspondence Factor Analysis and Ascending Hierarchical Clustering. The results have confirmed that technical traces observed under the microscope can effectively be correlated with different categories of craftsmen. Some traces are the indication of a lack of technical expertise shown by the absence of control of the tool and the imprecision of the gestures. On the contrary other traces such as the use of various techniques indicate technical mastership. The fact that engravers with different levels of technical ability used specific types of raw materials indicates that a social distinction relating to skill was made. The most obvious explanation is that the various levels of expertise were socially recognized in a double-level relationship

Fig. 8. Bone fragment (pelvis) with unknown function. Two complete horses presenting traces of a great technical inexperience have been engraved on both sides. Las Caldas, 879. Index: −5.

such as “masters” and “apprentices”, though the words are probably not accurate.

Unfortunately, the spatial context of most of the Cantabrian and Pyrenean Magdalenian decorated objects is lacking, which prevents us from examining the spatial distribution of decorated objects with varying degrees of technical accomplishment and in association with rock art, habitation structures, and other types of artefacts such as lithic tools. The absence of archaeological data does no allow us to study how the relationship between master and apprentices was conceived and integrated in the social practices. By comparison with ethnographic data and with the domain of flint knapping where more data are available, we assume that the transmission of knowledge was essentially made by imitation.

Another conclusion of this work is that the production of portable art is quite uneven in different sites, as shown by the average values of the technical quality index. The proximity of Isturitz and Le Mas d'Azil, shown by the CFA and by the high value of their index is a remarkable fact confirming that both sites probably played a comparable role in the Pyrenean regarding the transference of technical knowledge, diffusion and creation of artistic objects. The role of certain sites as centres of creation was probably widely recognized among the groups participating in the extended social network. This could lead us to reconsider the concept of “*aggregation sites*” under another angle (Conkey, 1992). On the contrary, Las Caldas show a stronger proportion of works of medium or low technicity, which can indicate a different functionality with respect to the Pyrenean sites. It seems that the decorated objects at Las Caldas were probably made for the exclusive usage of the group, whereas at Isturitz, a massive serial production was intended for an extended diffusion. The situation may be linked to the small size of the site of Las Caldas and its seasonal occupation during the Middle Magdalenian (Mateos, 2002), in contrast with the permanent occupation of the large site of Isturitz.

The methodology used in this study has allowed us to confirm the observations of numerous earlier works, offering a reliable statistical basis. The next step will be an extension of the analysis to thoroughly study the mechanisms of knowledge, transmission and cultural exchange between human groups during the Tardiglacial period at Western European scale.

Fig. 9. Slab from Las Caldas (2579) engraved with three ibex (Corchón, 2007-2008). This piece belongs to the second group of engravings, with a “quality index” of 1.

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