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EXPERIMENTAL PROGRAMMES WITH RETOUCHERS: WHERE DO WE STAND AND WHERE DO WE GO NOW?

Abstract

This paper presents a critical review of the experimental works with bone retouchers that have been published since the beginning of research about this type of tool. The aim of this review is not the recollection of references *per se*, but a critical evaluation of different studies. This critical synthesis will show where we are today from a theoretical and methodological point of view. A number of ideas on how to improve and expand the scientific research about retouchers will be proposed together with a range of open archaeological and experimental issues, which can be addressed by the research community in the years ahead.

Keywords

Experimental archaeology; Retouchers; Bone tools; Middle Palaeolithic; Methodology

Introduction

This work focuses on the contributions of experimental archaeology to the study of bone retouchers; thus, it is necessary to begin with a brief explanation and discussion about this theoretical and methodological approach.

Experimental archaeology is a methodological framework based on actualism and empiricism, the core concepts behind a systematic, quantitative and inferential study of archaeological evidence. The works of Coles (1973, 1979), Reynolds (1994), Baena (1997) and Callahan (1999) laid the foundations for the formal development of this theoretical and methodological approach, and these works also contain the main proposals for its practical application. The aforementioned authors present experimental archaeology as a mechanism to propose and test explanatory hypotheses about archaeological evidence. This inferential framework can be used as a tool to validate or falsify hypotheses.

For experimental archaeology to have true scientific rigour, it must meet certain requirements of objectivity and control. These criteria have been specified in several studies (Baena, 1997; Callahan, 1999). It is also necessary that such experiments are integrated into a broader framework of analysis and interpretation of archaeological evidence. And, most important, the ultimate goal of this general framework cannot be the anecdotal analysis of the materiality of archaeological objects. Rather, the goal must be to propose explanatory models of past human societies.

Bone retouchers in context

Bone retouchers are a common type of tool in the Middle Palaeolithic, but are not confined solely to that period. These tools are percussion implements made of bone; most typically they are unmodified or barely modified splinters from long bones (including metapodials) of ungulates. These tools are used to retouch stone tools, both in the sense of shaping an implement (e.g., a side-scraper) and for rejuvenating a dull edge. In most cases, when archaeological retouchers have been studied in depth, it was determined that they were used in percussion tasks. Only in a few cases were they used in pressure-style retouching tasks, the use traces from which are very different from those produced by percussion.

In the early 20th century, Henri-Martin (1906) first determined the existence of this specific type of bone tool among the faunal remains of La Quina, France. These implements were diaphyseal splinters from ungulate bones, and they were possibly used to retouch Mousterian lithic tools. At this early stage, some functional uncertainty can be perceived in the texts, and researchers alternatively proposed that the bone splinters were active elements (mallets/percussion tools, *Fr. maillets/percuteurs*) or otherwise passive (anvils, *Fr. enclumes*) when writing about how they were used. At about the same time, de Mortillet and de Mortillet (1910) defined the compressor (*Fr. compresseur*) as a bone tool that was characteristic of the Solutrean period, used for pressure retouch activities. In most cases, the label of Middle Palaeolithic bone tools as anvils was soon discarded (Siret, 1925), and throughout the first half of the 20th century, these tools originally described by Henri-Martin were typically identified by the term "compressor-retoucher" (*Fr. compresseurs-retouchoirs*). But, as was typically of most works from period, there was no consideration about how individual objects, or even whole assemblages, could have been used.

In the early 1960s, Bordes (1961) includes Solutrean bone compressors in his typological lists, and stated that they were used differently than the diaphyseal splinters with impressions that came from Mousterian sites.

Confusion stemming from variability in bone retouchers nomenclature was a constant even beyond the 1960s. But, during that decade, development of the archaeological, anthropological and historical disciplines, and the new visions of archaeological science, gave a clearer idea of the nature of such tools.

In a synthesis of the European continent, Taute (1965) enumerated a large collection of retouchers in hard animal tissues (mostly bones, but also teeth and antler) with a wide chronological perspective, ranging from the Palaeolithic to the Neolithic. This work included retouchers from several Middle Palaeolithic sites in Central Europe. The bulk of Taute's sample was made of epiphyseal and diaphyseal splinters with impressions, which led to the conclusion that the tools are bone retouchers – used for retouching lithic implements with a percussion (not pressure) technique.

Since the early 1970s, researchers have found more Palaeolithic bone retouchers throughout Europe, mostly in Middle Palaeolithic (particularly Mousterian) sites. Some important examples include Kůlna Cave in the Czech Republic (Valoch, 1988), Abrigo Tagliente in Italy (Leonardi, 1979) and Peña Miel in Spain (Barandiarán, 1987), but there are dozens of sites where the presence of these tools was detected and published. Throughout the 1970s to 2000s, dozens of new and old sites with retouchers were documented and published (Mozota, 2012).

Bone retouchers were also documented in several deposits from the European Upper Palaeolithic in France, such as the Protoaurignacian and Early-to-Evolved Aurignacian layers from Gatzarria (Saenz de Buruaga, 1987; Tartar, 2012), or the Aurignacian from Grotte des Hyènes (Tartar, 2003) and Abri Castanet (Tartar, 2012) .

For the Solutrean, there are examples too, such as Le Petit Cloup Barrat in France (Castel et al., 2006). And for the Magdalenian, bone retouchers were found in La Garenne (Rigaud, 1977), Isturitz and La Vache (Schwab, 2005), all from France, and in the German sites of Gönnersdorf and Andernach (Tinnes, 2001).

Outside Europe, retouchers have been documented in other Pleistocene contexts, such as in the Middle Stone Age layers at Blombos Cave, South Africa (Henshilwood et al., 2001) and in the Middle Palaeolithic of Umm-el-Tlel (Syria) (Boëda et al., 1998) and El Harhoura (Morocco) (Michel et al., 2009). In the Americas, the presence of bone retouchers has been documented in various contexts of prehistoric hunter-gatherers. There is a type of tool defined by Jackson (1990) as an end-side retoucher (*Sp. retocador extremo lateral*). This type of tool is virtually identical to the concept of retoucher on diaphyseal splinters from European Palaeolithic sites. *Retocadores extremo laterales* have been found in Paleoindian contexts (Pleistocene) at Fell 1 in Magallanes, Chile (Massone and Prieto, 2004). There are also some examples from the recent period (Holocene) in Magallanes at the site of Orejas de Burro 1 (Lorena-L'Heureux, 2008).

As for theoretical and methodological developments, during the early 1990s Chase (1990) resumed the study of the bone tools from La Quina. He analyzed a selected sample of materials and concluded that many bone splinters were used as retouchers for percussion tasks. Chase (1990) integrated this analysis into an explanatory model of Middle Palaeolithic tools, whereby retouchers were proposed as one of the key elements reflecting Neanderthal cognitive (dis)abilities (see also Dibble, 1989). While this proposal has been disproven by many studies about Neanderthals (e.g., d'Errico, 2003; Zilhão, 2007; Hayden, 2012) its lasting importance lies in the analysis of artefacts to answer central questions about prehistoric human groups.

The Ph.D. dissertation of Vincent (1993) is also important from a methodological perspective, in that she proposed new approaches that reflect advances in archaeozoology, taphonomy and bone technology from the preceding decades.

In 2002, a synthesis of the European Palaeolithic was published (Patou-Mathis, 2002), incorporating reviews of many retoucher assemblages, mainly from the Mousterian and some examples from the Upper Palaeolithic. The work is organized in a series of standardized typological datasheets, and some use traces are studied to make functional inferences, but this is not systematic.

Experimental archaeology and bone retouchers: a historiographical perspective

A century of experimental work: from the early 20th century to the beginning of 21st century

Siret (1925) performed one of the first detailed experiments of lithic retouch with bone fragments. He conducted these activities within the framework of discussion about the role of bone splinters with impressions that had been recognized at La Quina (Henri-Martin, 1906) and other Mousterian sites. Choosing between the different hypotheses of the time, Siret concluded that the diaphyseal fragments with impressions were retouchers, not compressors or anvils, used as active elements for working flint tools. He further stated that these tools were used in pressure flaking tasks instead of percussion. He considered that the lithic tool was held in one hand and pressed against the bone tool, which was held in the other hand, until the detachment of a retouching flake.

During this period, experiments were always replicative and based on subjective and qualitative observations. In most cases, little data on the specific experimental procedures were offered.

Semenov (1956) defined some features of compressors after studying a pair of bone fragments from the Upper Palaeolithic of the Soviet Union. The blanks he studied showed two different use areas located at opposite ends of the bone fragment. After comparing the traces of use with experimental materials, he interpreted the marks as the result of pressing the compressor on the lithic edge. Semenov's most important contribution is not the study of these particular tools, but rather his inclusion of an explicit methodology linking experimentation and the analysis of tool function. In addition, he provided the means to integrate these experimental studies of artefacts into general models for the explanation of past human societies; in this case, within the orthodoxy of historical materialism.

Moving towards the 1960s and 1970s, Feustel (1973) and Dauvois (1974) performed experimental studies that again linked the impressions on diaphyseal splinters with retouching lithics. Both works provided some important insight on the matter, but, like many others, these works are of limited scope because they do not explain their methodologies or the actual data generated by the experiments.

Rigaud's (1977) work contains an experiment to analyse the stigmata present on bone retouchers from the Magdalenian layers of La Garenne, France. Typical traces were longitudinal lines (*Fr. traits longitudinaux*), which can form cupules (*Fr. cupules*) of use when they are very numerous and concentrated (**Table 1**). Also documented were scrapings (*Fr. éraflures*), or thin grooves, which are formed when the protruding points of the lithic tool edge make contact with the retoucher at the end of the movement, often lateralized to the right in the case of a right-handed artisan. Rigaud also experimented with using the blanks as compressors for pressure retouch, and characterized such traces by the presence of primary and secondary striations, which were deeply engraved on the bone blanks. This pioneering study by Rigaud details both his methodological framework and development of experimentations, including the definition and quantification of variables and statistical analysis. However, as Rigaud focused the study on lithic elements, the use traces observed on bone retouchers were not studied with the same level of detail. Nevertheless, this work was the first to provide a classification of use traces into discrete categories. These traces were reasonably well defined and explained in mechanical terms.

In Italy, Leonardi (1979) described possible bone retouchers at Abrigo Tagliente and refers to the unpublished experimental works of Guerreschi. These experiments suggest that the archaeological bones were used in percussion (not pressure) tasks for re-

Table 1 Approximate equivalences between different classifications of use traces categories proposed by the researchers and works mentioned in the text. Use traces on the same lines indicate a general equivalence.

Rigaud 1977	Vincent 1993	Ahern et al. 2004	Rosell et al. 2011	Mallye et al. 2012	Mozota 2013	Daujeard et al. 2014
Fr. Traits longitudineux	*Fr. Hachures and Entailles**	**	Shallow striations and deep striations #	Scores (rectilinear/ sinuous, convex/ concave)	Linear impressions	Hash marks or hatchings and grooves*
Fr. Éraflures	—	**	—	—	Striations	Sliding striations
—	*Fr. Cupules*	**	Grooves	Pits (triangular/ ovoid)	Trihedral impressions	Cupules or chattermarks
Fr. Cupules	—	**	—	Scaled area	Massive chipping	—

* Vincent (1993) Fr. "*Entailles*" and Daujeard et al. (2014) "Grooves" could also partially correspond to others authors' "Pits" (Mallye et al. 2012), "Trihedral impressions" (Mozota 2013) and "Grooves" (Rosell et al. 2011).

** Ahern et al. (2004) described punctiform pits and short linear channels, but their functional interpretation – see text- makes impossible to correlate these categories to other authors' classifications.

\# Rosell et al. (2011) classification of traces is based on the taphonomic studies of Blumenschine and Selvaggio (1988) and Blumenschine et al. (1996).

touching lithic tools, but no details about the specific content of the experimental works were provided.

In the 1970s and 1980s, Lenoir (1973, 1986) offered an experimental and archaeological study of Quina-type Mousterian industries, focused on lithic technology. These works marginally addressed the use of bone retouchers, and information on their use was mostly of an anecdotal or qualitative nature. Later, ETTOS (1985) published the accounts of several experimental initiatives geared towards Palaeolithic bone materials, including retouchers. This was a synthetic work, but with just a few theoretical and methodological details.

In the early 1990s, several new studies substantially improved the experimental understanding of archaeological bone retouchers. Boëda and Vincent (1990) linked the Quina-type retouch with the use of bone retouchers, and the Ph.D. dissertation of Vincent (1993) included an experimental programme to analyze bone splinter use in percussion tasks. Vincent characterized and classified three types of traces (see **Table 1**): cupules (*Fr. cupules*), which are rounded marks; hatchings (*Fr. hachures*), which are elongated and thin marks; and grooves (*Fr. entailles*), which are deeper and wider marks with an inner rim. Hatchings were the most common traces. Retouchers were classified by Vincent as soft hammers used for the manufacture and retouching of flint tools. The author noted that "semi-dry" bone was optimal for use in retouching tasks. Completely dry or green bone was considered less suitable for percussion retouch. In addition, Vincent noted that bones from adult animals were preferable because of the larger mass and density required for effective percussion. Vincent's work was a milestone in the study of bone retouchers, and her classification of stigmata into discrete categories has been used frequently by other authors. This work focused on description and classification, leaving aside inferential questions; there is a slight predominance of qualitative over quantitative criteria, yet still a major breakthrough in experimental studies of bone retouchers.

Also in the early 1990s, Chase (1990) studied a number of retouchers from La Quina (Locus 2), together with an experimental sample. Chase stated that documented traces of use in archaeological tools were identical to those from his experimental programme. He described the stigmata as short, deep, and sub-parallel marks with V-shaped sections resulting from the impact of a lithic edge against bone matter. These traces were concentrated in areas of use that eroded very quickly. According to Chase, the stigmata observed in bone retouchers corresponded to very short periods of use: between five and eight seconds. Such use served to rejuvenate a single lithic edge, and after that, the retoucher was abandoned. Chase's (1990) work is of great interest because it explicitly integrated an explanatory model of Middle Palaeolithic stone tool management (see also Dibble, 1989). In this model, bone retouchers were an impromptu tool, used for a few seconds, then abandoned. Retouched flint tools were the result of edge rejuvenation, with no previous conceptualization or planning of the tool's shape. From a practical point of view, this model severely underestimated the use life of bone retouchers. Later researchers determined that the cost in time for retouching a lithic tool is relatively short, but longer than the five to eight seconds predicted by Chase. More realistic time spans range from half to a few minutes (Mozota, 2012), depending on many variables, including the size and morphology of the lithic implement, the retouching technique, the *savoir-faire* of the maker, etc.

A study by Malerba and Giacobini (1998) presented an analysis of bone retouchers from northern Italy (Fumane, Tagliente, and San Bernardino) and several pieces from La Quina. These archaeological materials were compared to experimental implements, and the authors confirmed their use in percussion tasks. Again, experimental protocols were not explained in great detail, and it appears the entire exercise was largely replicative, which allowed the authors to confirm (or reject) an *a priori* hypothesis on how the tools were used.

Armand and Delagnes (1998) studied a sample of retouchers from layer 6C of Artenac, a La Ferrasie sub-type Charentian Mousterian site in France. The work included the results of experiments performed with 33 diaphyseal splinters of *Bos taurus* that were used to retouch flint tools. A number of parameters were considered, including angle, trajectory and direction of the percussion, force of the blow, type of hand grip and passive vs. active roles of the bone tool. With a strategy to replicate the bone retouchers from Artenac, they varied the parameters until they achieved the combination that generated the same sub-type of retouched side-scrappers present in the archaeological series. Armand and Delagnes (1998) used the same categories of stigmata listed by Vincent (1993): hatchings (*Fr. Hachures*), cupules (*Fr. Cupules*) and grooves (*Fr. Entailles*). Each stigma type was associated with a specific combination of parameters. Hatchings (*Fr. Hachures*) occurred with percussion angles around 40°, linear trajectories, an oblique direction, and a loose grasp of the retoucher. Cupules (*Fr. cupules*) resulted from strong percussions and were associated with irregularities in the edge of the lithic tool or the retouching of the butt of the flake. Finally, grooves (*Fr. entailles*) were related to percussions with re-entrant (parabolic) trajectories, with angles between 120° and 160°.

Armand and Delagnes (1998) also noted that no stigmata were recorded on the bone retoucher in two experimental situations. Specifically, no stigmata were produced while striking sharp edges with very acute percussion angles or during passive use of the retoucher (bringing the lithic piece to the bone). The authors also point out the frequent presence of scrapings on the archaeological retouchers, concentrated in the active zone. These scrapings are interpreted as a preparation of the area prior to use. The work of Armand and Delagnes (1998) is of great interest because they define and make explicit the most important elements of their experimentation. Still, the programme is replicative and deductive, with a very narrow focus on determining the type of retouch that was performed at the site of Artenac. Most introduced variables are not really quantitative, and qualitative considerations dominate the study, except for some morphometric measurements. These measurements are nevertheless of great interest because they were used to explore the dimensions of retouchers in relation to the size of the other bone splinters not employed as retouchers.

Bourguignon (2001) conducted an experimental programme to study the processes of shaping Quina-type tools by retouch. The author began by defining a number of technical parameters which determined the type of retouching. Bourguignon noted that there was a significant degree of overlap between the various types of hammers or percussion tools (soft, hard, "hard-soft") in terms of their potential use. Lower mass, density or elasticity of a bone hammer could be, to some extent, overcome with changes to the applied force or the percussion gesture. This work has a strong qualitative component of *savoir-faire* gained through personal experience, which significantly reduces its potential for scientific inference.

In the collective work dealing with retouchers and similar tools edited by Patou-Mathis, Malerba and Giacobini (2002) presented the study of retouchers from La Quina, and the Italian sites of San Bernardino and Fumane. Experimentation confirmed the use of bone splinters in percussion tasks for retouching sharp flint edges. The authors also found that right-handed artisan produced some deviation to the right side of retouchers, both in trace orientation (slightly oblique) and position of the areas of use (closer to the right side of the blank). This followed Rigaud's (1977) experimental realization that human laterality (predominant use of one hand over the other) can be detected in bone retouchers.

In the same collective work, Valensi (2002) presented the study of several phalanges of *Rangifer tarandus* and *Bos sp.*, used as retouchers. Based on experimentation, she deduced that the archaeological traces were produced on fresh bone. Moreover, each species was associated with a particular type of retouch: the *Bos* phalanges were used to perform abrupt retouch, while *Rangifer tarandus* were used for flat and invasive retouch. This work is based on a replicative-deductive strategy to infer how a particular task, detected in the archaeological material, was performed.

Ahern et al. (2004) studied the bone retouchers from layers F-G at the Vindija archaeological site in

Croatia. The authors conducted an experiment to match the traces of use from the bone retouchers with two different types of retouch present in the lithic assemblages. Two types of marks, one due to percussion and the other due to pressure flaking, were observed in the experiment (see Table 1). The marks made by percussion were punctiform pits with scaling on the edges, while the marks made by pressure were short, linear channels with U-shaped sections. The authors noted some differences between the experimental results and the archaeological sample: in the archaeological tools, percussion traces were more lenticular, and traces of pressure were deeper. Again, this replicative-deductive strategy limits the scope of experimentation and its potential for scientific inference. And in this case, the authors used their own specific classification of stigmata. Their results suggest that either the use traces do not correspond to the those documented by other researchers, or these marks only represent a few, very specific sub-types. Finally, it is important to note that the experiment included only one retoucher used for two different tasks.

David and Pelegrin (2009) studied two bone tools from a Mesolithic context. Both tools had two different uses: as chisels and as retouchers. Ten experiments with bone blanks were designed to study stigmata produced on bone surface by different activities, all related to flint management. According to the authors, the types of traces documented when retouching flint implements correspond to the classification of Vincent (1993). Use zones were located at the ends of bones, but not too close to the edge. The use of retouchers in pressure tasks produced lateralized areas with concentrated stigmata, located to the right side of the central axis. This lateralization was also present in the tools used for percussion retouch tasks. The researchers documented striations or secondary lines with pressure retouch, but not for percussion tasks. David and Pelegrin (2009) concluded that the traces present in the two archaeological retouchers were related to pressure retouch tasks. Their work is of great interest as an exploratory exercise of ten different tasks that could imply the use of bone retouchers, especially since some of the tasks were not usually considered in other experimentations. However, the total number of experiments, and the fact that each individual task is completely unique, makes it virtually impossible to confirm that the documented features are actually relevant, and they cannot be used for quantitative analyses.

Where do we stand? Experimentation with bone retouchers in recent years

Rosell et al. (2011) presented several tools from the Lower Palaeolithic site of Atapuerca, Spain, including a diaphyseal splinter used as a retoucher. The supplementary material of the paper details 16 experiments with dry and fresh *Bos taurus* bones used to retouch lithic blanks of quartzite and flint. The authors used a classification of traces (see Table 1) based on the taphonomic studies of Blumenschine and Selvaggio (1988) and Blumenschine et al. (1996). These works refer to the marks left by stone tools on bones, but with emphasis on butchering and carcass processing, and not on the use of bone as a tool. Traces are classified as shallow striations (straight or slightly curved and shallow incisions), deep striations (straight or slightly curved and deep incisions) and grooves (wide and very deep marks with a trihedral or irregular shape). This is an interesting work because the authors chose different exploratory variables (two lithic raw materials to be worked and two states of bone) and control them with a high level of detail. But, being focused on a strictly deductive-replicative strategy, the study is of little utility beyond the characterization of the tool found in Atapuerca.

Tartar's (2012) synthesis work on Aurignacian retouchers included a well-defined, specific experimental programme about the use of these tools for retouching Aurignacian blades and for knapping micro-blades. While the scope of this work would improve with the inclusion of more quantitative data, it is the author's observations about the technical mechanisms that influence the formations of stigmata and the appreciation for the choices available to the artisan using the retoucher that are relevant for current research.

My own experimental programme (Mozota, 2012, 2013, 2014) includes the largest experimental sample analyzed in detail and published to date: 38 experiments on the fragmentation of large ungulate long bones to study various aspects of blank collection for these kinds of tools and 177 experiments on retoucher use.

My work does not deal with experimental archaeology from a strict replicative perspective, nor delves into *savoir-faire*, but builds a scientific programme based on the systematic collection and organization of data, quantitative treatment of the data and a hypothetico-deductive structure. The first experimental series was designed to analyse the collection and use of retouchers made of ungulate bone splinters. Specifically, I studied the process of fracturing a sample of *Bos taurus* and *Cervus elaphus* long bones (including metapodials). The blanks obtained were then used in a second phase: retouching quartzite and flint implements. The array of possible retouching tasks and the selection of animal and lithic raw materials were based on the archaeological inventories from a series of Mousterian sites in the northern Iberian Peninsula (Mozota, 2012).

In the first series of experiments (blank collection), the goal was to study the physical mechanisms of long bone fracture, the actual stigmata caused by percussion and the products of fragmentation. The analysis incorporated a series of controlled and independent statistical variables. I also studied the most relevant morphological and metric traits of every usable blank obtained in the experiments. Two main strategies of bone fracturing were considered: one aimed at marrow extraction, and the other aimed at the production of blanks for retouchers (**Figure 1**).

Figure 1 Blank collection experiments by M. Mozota. The photographs show the fracturing of deer metapodials within a blank-producing strategy.

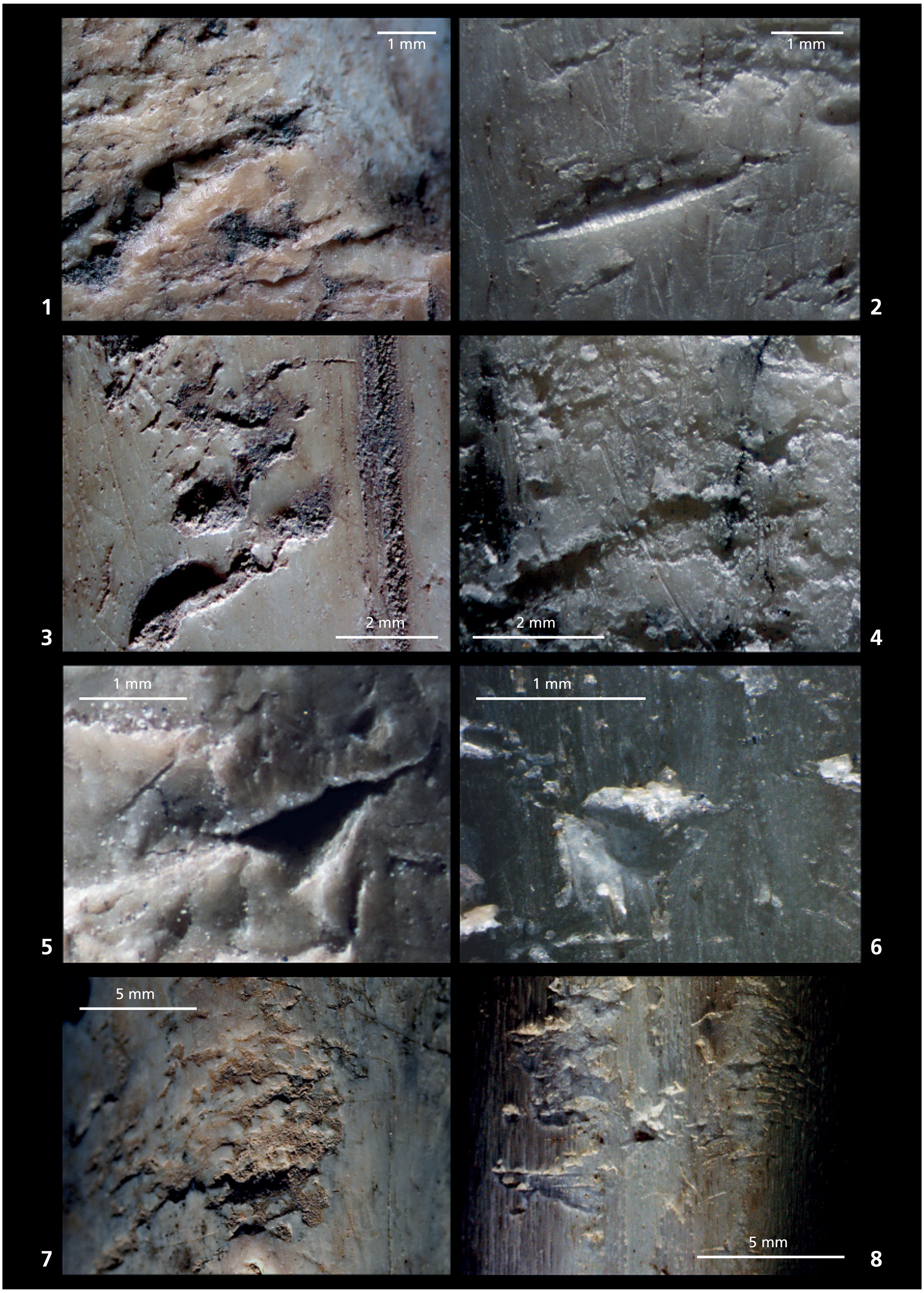

Figure 2 Traces of use in archaeological and experimental bone retouchers from Mozota (2015). (1) Linear impression detail, Peña Miel Level G. (2) Linear impression detail, experimental sample. (3) Striations and linear impressions in direct association, Peña Miel Level G. (4) Striations and linear impressions in direct association, experimental sample. (5) Trihedral impression, Peña Miel Level G. (6) Trihedral impression, experimental sample. (7) Widespread chipping, Prado Vargas Level 4. (8) Widespread chipping, experimental sample. This figure was first published in Mozota (2015) under a Creative Commons 3.0 Attribution-NonCommercial-NoDerivatives License.

In the second set of experiments (retouching), the goal was to understand the formation of different use traces and how these traces related to different retouching tasks and other variables. Using the same systematic approach, the analysis followed a series of quantifiable and independent variables. Additionally, I searched for consistent and recognizable patterns of use traces related to specific tasks that could be identified in the archaeological record. The use traces were studied mostly through quantitative variables (obtained from artefact inventories, counting and measurement of stigmata); qualitative observations were also recorded during the process.

I defined three categories of stigmata, or use traces, through three specific criteria: identifiability, repetition and univocity. In other words, the stigmata must be recognized and differentiated without any degree of ambiguity and frequently present on the used blanks. With that, the categories of stigmata were linear impressions, trihedral impressions, and striations (see Table 1, Figure 2).

Linear impressions are straight or slightly curved elongated marks, narrow and deep, with a V-shaped profile. These impressions are produced by a lithic edge impacting the bone surface, and are the most common retoucher use traces. Their detailed morphology can be quite variable, depending on the force applied, percussion trajectory, working angle, lithic edge configuration, blank shape, etc. When considering these numerous variables in relation to the final detailed morphology of the impressions, they showed a high degree of equifinality. Trihedral impressions are deep, with a negative trihedral shape, and are produced by the impact of an apex of the lithic edge against the bone. Striations are straight or slightly curved elongated lines, often directly associated with linear impressions (typically perpendicular or sub-perpendicular to those traces). Striations appearing in concentrations can be mistaken for scrapping marks related to butchery or blank preparation. Striations are usually produced when lithic apexes scrape against the bone surface during percussion or the application of pressure, before the lithic edge "bites" the blank producing a linear or trihedral impression.

In addition to those stigmata, another type of widespread use-wear was documented: chipping. This can be defined as alterations to the cortical bone surface due to use, located on the active areas of the blank. These alterations are produced by the concentration of impacts on a restricted area, or what Rigaud (1977) called cupules, but not the *Fr. cupules* in Vincent's (1993) classification.

For the collection phase, results indicate that when the objective was bone marrow extraction, percussion produced a higher number of non-usable splinters and a more heterogeneous morphology of potential blanks. In contrast, the blank production strategy produced a lower number of non-usable splinters and a less heterogeneous blank morphology (Mozota, 2013).

For use areas, a clear pattern of lateralization became evident when considering the position of traces on the blanks (Mozota, 2013). This interesting result is directly associated with the fact that the experimenter was right-handed. The study of use traces also yielded other conclusions related to bone freshness, retouching task, lithic raw material and intensity of use (Figures 3 and 4).

Dry bone shows fewer linear impressions than fresh bone when subjected to the same levels of use intensity. Also, the appearance of linear impressions on a dry bone is different from the impressions made on a fresh bone. When considering the stigma features in relation to modes of retouch, a difference arises between pressure and percussion (including both Quina and simple types of retouch). Percussion is characterized by longer linear impressions, rare massive chipping on use areas and a relatively high incidence of trihedral impressions. Pressure retouch is characterized by the opposite: shorter linear impressions, an increased presence of massive chipping and a lesser occurrence of trihedral impressions. Among percussion implements, Quina and simple retouching tasks were compared. Quina retouch is characterized by longer and more abundant linear impressions, a scarcity of striations and a high incidence of trihedral impressions and massive chipping. The opposite is true for simple retouch: fewer impressions per use area, a higher presence

Figure 3 A few of the blanks used in retouch experiments by M. Mozota. (1- 6) fresh bone splinters of *Bos taurus* long bones. (7-12) fresh bone splinters of *Cervus elaphus* metapodials. (1) Quina retouch, flint. (2) Simple retouch, quartzite. (3) Pressure retouch, flint. (4) Pressure retouch, flint. (5) Quina retouch, flint. (6) Simple retouch, quartzite. (7) Quina retouch, quartzite. (8) Quina retouch, quartzite. (9) Simple retouch, quartzite. (10) Quina retouch, flint. (11) Quina retouch, quartzite. (12) Quina retouch, quartzite.

of striations and a low incidence of trihedral impressions and massive chipping.

Combining this experimental programme with archaeological studies of archaeological retouchers, lithics, and other faunal remains from Mousterian sites in the Iberian Peninsula has contributed to general models of Neanderthal behaviour from this chronology and geographical area (Mozota, 2009, 2012, 2015).

Mallye et al. (2012) studied the Mousterian bone retouchers of Noisetier Cave (France) and detailed an experimental programme for the interpretation

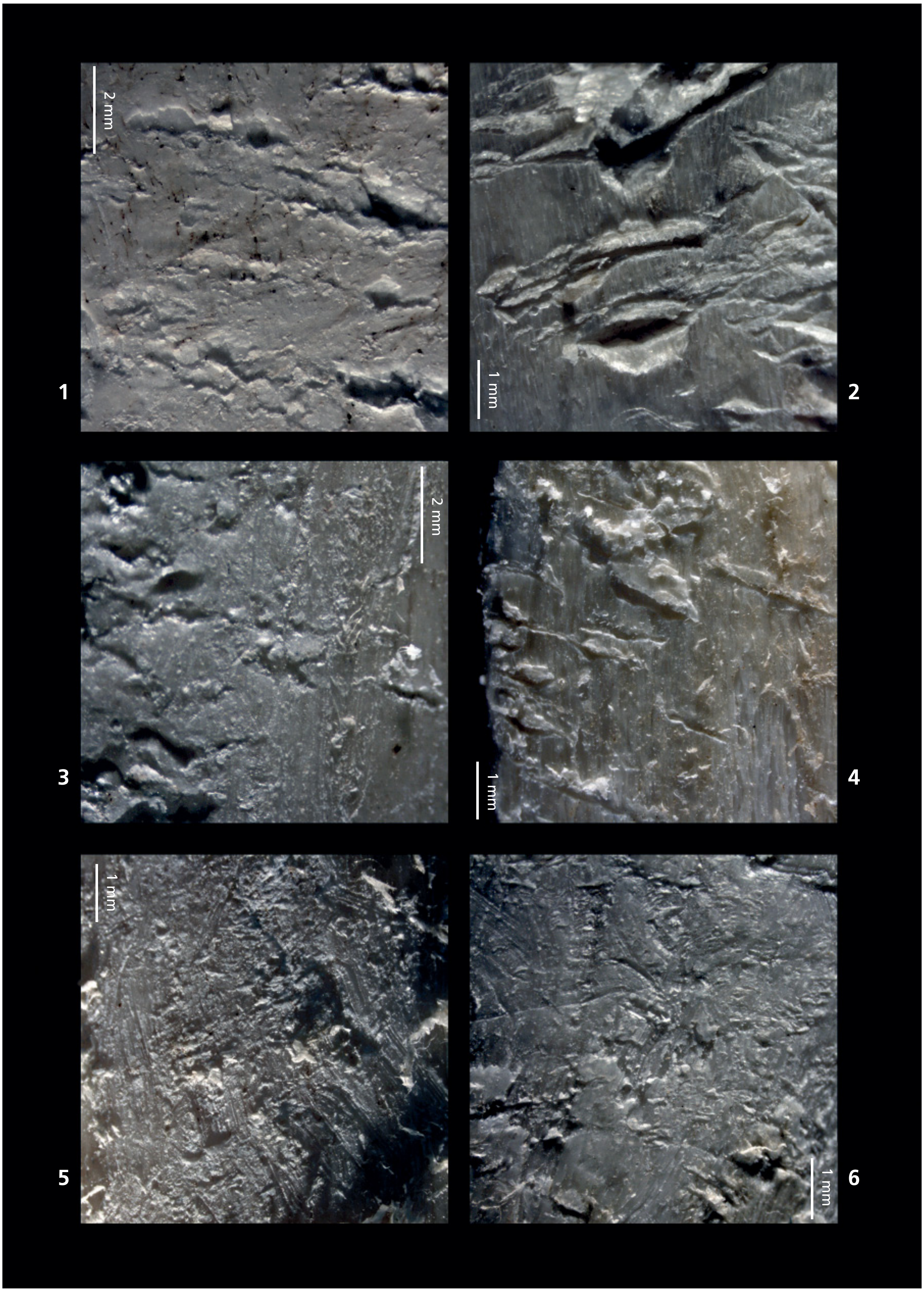

Figure 4 Low magnification images of use traces from different experimental retouchers. (1) Traces on dry bone produced by Quina retouching of flint. (2) Traces on fresh bone produced by Quina retouching of flint. (3) Traces on fresh bone produced by Quina retouching of quartzite. (4) Traces on fresh bone produced by simple (direct, non-invasive) retouching of flint. (5) Traces on fresh bone produced by pressure retouch of quartzite. (6) Traces on fresh bone produced by pressure retouch of flint.

of traces detected on the archaeological tools. They conducted 73 retouch experiments with fresh and defatted bone on tools made of quartzite and flint. These researchers studied the active areas and classified their positions on the bone blanks in some discrete categories. They also classified stigmata into two groups: pits and scores (see Table 1). Sub-classifications were added to each group based on a more detailed morphology: triangular and ovoid pits; and rectilinear/sinuous and smooth/rough scores. Entire use areas were also classified into discrete types: hatched (with a predominance of rectilinear scores), pitted (predominance of pits) and scaled (with massive chipping).

The experimental programme of Mallye et al. (2012) allows researchers to infer the worked material (i.e., quartzite or flint) from the stigmata and appearance of the use areas. To a lesser extent, the state of bone (fresh or defatted) could be inferred. They did not find a relationship between the use of a dominant hand and the position of the areas of use. This work brings important advancements in the planning of an experimental programme, with clear and well-organized variables, a relevant quantification of the results and a statistical treatment of the data. Additionally, this analysis is integrated into a more general study of the archaeological evidence of the subsistence patterns and ways of life of the Neanderthal groups that lived in Noisetier Cave. The main limitation of this study is the approach to the position of the use area. With its general classification of use areas into large and subjective categories the study may lack the precision required to detect relevant differences in lateralization of the active areas. While this is not an actual flaw, strict adherence to the classification scheme proposed by Mallye et al. (2012) imposes limitations on the study of handedness and brain lateralization.

Finally, Daujeard et al. (2014) studied a number of faunal assemblages with bone retoucher from southeast France, supported by an experimental programme. These researchers adapted and modified the stigma classifications of Vincent (1993), defining four categories (see Table 1): cupules or chattermarks, hatchings or hash marks, grooves and sliding striations. This work presents all the data very efficiently and in great detail, particularly with regard to the archaeological materials. However, it seems the experimental programme was not aimed at drawing general inferences about the tool use, but was designed to create categories to classify and describe the objects and, eventually, the archaeological assemblages.

Overall, the experimental study of bone retouchers has been a collective process involving many researchers; it began in the first decade of the 20th century and is still going on today. It originated with qualitative descriptions of stigmata, followed by the analytical classification of these traces of use. Finally, in more recent times there has been notable progress towards a fully functional understanding of the formation and development of use traces. At the same time, more systematic research programmes are being developed, with a more complete and rigorous quantitative basis.

Where do we go, now? Current research shortcomings and prospects

General research questions

Despite the long and fruitful journey, there is still work to be done. Researchers should adjust current experimental work to the highest standards of scientific research programmes in prehistoric archaeology to ensure that we are doing the best science possible.

First of all, it should be clear that an experimental programme may include various exploratory trials or qualitative approaches, but research cannot be limited to these activities. These qualitative studies have no real capability to make scientific inferences, neither are they usually verifiable or reproducible by other researchers. Such exploratory approaches are limited in scope because they have no real explanatory power of studied phenomena. Therefore, we should conduct our experiments (or at least the main phase of our experimental programmes) within the constraints of what Callahan (1999) called level III of scientific reliability, and Baena (1997) considered rigorous models with high control of variables.

Moreover, it is not acceptable when the variables studied in our programmes are not adequate for quantitative analysis of the data (Shennan, 1997). When possible the variables must be numerically continuous. If certain features of the tools cannot be measured properly, discrete numerical variables can be used. And if this is not possible, binary, ordinal and nominal variables should be considered; however, these types of variables are less informative by definition, and fewer statistical tests can be applied to them, resulting in less overall inferential power. So, as a general strategy we should measure every stigma whenever possible rather than rely on simple counts (which is also important). And, when possible, we must count all the stigmata of a type rather than simple documentation of its presence or absence. Although these procedures have been developed in recent years, it is clear that there is still great room for improvement. Such strategies will produce data with more explanatory potential, especially when we incorporate the data with independent variables start to sort out how these variables influence the number and dimensions of stigmata.

There is another problem of a theoretical-methodological nature that is common among experimental approaches to bone retouchers: the lack of an integrated analysis of archaeological artefacts within a general framework of research on past human societies. The study of prehistoric artefacts cannot be a goal in itself. On the contrary, such studies should always be oriented towards obtaining data that can be integrated into a general explanation of human behaviour.

We cannot forget that human beings, not objects, are the ultimate subjects of our work. There is an overabundance of research that is impeccable from a technical point of view but makes almost no relevant contributions to the general state of knowledge about past human groups. To correct this situation, researchers should make explicit their research objectives, along with reporting their final results. From an experimental perspective, it is necessary to study the role of bone retouchers within the social and economic dynamics of the human groups we study. We also need to integrate the study of these tools in the general framework of how human behaviour changed over time.

So far, studies have shown that bone retouchers have a great potential to infer the economic behaviours and social organizations of past human groups (Mozota, 2009, 2015; Jéquier et al., 2012; Mallye et al., 2014). Thus, these prospects should be further exploited. Bone retouchers form a conceptual bridge between the procurement of faunal resources and the management of mineral resources. In that sense, the analysis of bone retouchers can provide vital information for understanding how faunal and lithic management are integrated into the overall subsistence strategy, and ultimately, into the economic and social organization of past human groups.

Specific research questions

CATEGORIES OF USE TRACES For the study of the use traces, most researchers have chosen to separate stigmata into a series of discrete categories (see Table 1), which are not only useful on a descriptive level but also allow for functional inferences based on their measurable characteristics. There are several considerations to make in this respect. The first issue to consider is that when publishing our experimental programmes, we must make explicit the criteria that we followed to distinguish between stigma types. Given the importance of stigma categories as the basis for all subsequent study, the criteria that define them must be made explicit. If possible, stigma categories also must be explained in functional terms, i.e., how each type of stigma is created, from a technical and mechanical perspective.

Another issue directly related to the classification of the stigmata is the proliferation of different classifications used by different authors. In this sense, there is nothing intrinsically right or wrong with using the classification of a previous author, modifying existing classifications, or even creating a new one. All of these options should be considered valid strategies. But most importantly, the specific classification must be evaluated on the basis of its methodological validity and its applicability. This is precisely why it is important to explain the criteria used for a new system of classification. Additionally, if a modified or new classification is offered, the authors must explain the differences between their classification and the classifications already proposed by others. Creating new classifications without providing the terminological equivalents to match them with the works of others should be discouraged. This impedes comparisons across multiple studies and generally reduces the scientific potential of the work made by the whole community of researchers.

BLANK COLLECTION One of the least explored aspects of the experimental approach to these tools is the collection of bone blanks: splinters that are selected and used, and therefore become bone retouchers. The *a priori* assumption in most studies on archaeological retouchers is that there is an impromptu selection of blanks – these bone splinters were just picked up from among the faunal remains consumed at a dwelling place. In some cases, the morphometry of archaeological blanks has been analyzed in comparison with other faunal remains (Armand and Delagnes, 1998; Mallye et al., 2012), but experimentation in this direction is almost nonexistent (but see Mozota, 2012, 2013).

There are important issues regarding the collection of blanks that can be explored and possibly answered by experimentation. In particular, it is important to evaluate (i.e., confirm or deny) the possible intentional production of blanks from long bones and metapodials, which has been proposed for some Middle Palaeolithic sites (Mozota, 2009; Jéquier et al., 2014). It is also important to explore the possible existence of such production at other locations and in other time periods. The scope of experimentation needs not to be limited to answer whether an intentional production existed, but can also be used to better understand the degree of blank selection that may have occurred in different archaeological contexts. Experimentation can also help to answer the question of which criteria human groups used for selecting retoucher blanks. All these aspects can provide relevant information about the cognitive abilities and the socio-economic organization of human groups at different times and places.

PREPARATION OF BLANKS Another potentially important area of research on bone retouchers is the preparation of blanks. It has been proposed that certain assemblages of bone retouchers were prepared before use – scraping the active surface with a lithic instrument (Vincent, 1993; Armand and Delagnes, 1998). Certain experimental qualitative observations claim that scraping is necessary for using fresh bones, since the periosteum must be removed from the active areas to enable use as a retoucher (Vincent, 1993; Armand and Delagnes, 1998). In my experience, removing the periosteum is a simple and easy task, and it improves the performance of the retoucher, but is not necessary in all cases (Mozota, 2012). Moreover, in many cases much of the periosteum is removed during the actual fracturing of the bone and is not necessary to scrape the blank afterwards (with a lithic tool or otherwise). Therefore, this issue is an ideal topic to be re-evaluated by an experimental programme using quantified variables. For this work, I believe that experimentation should include a blank collection phase with a special interest toward anatomical parts, taxonomic origin and processing of animal carcasses.

There is another issue concerning the possible preparation of the blanks that has barely been explored, either through experimentation or mere observation of archaeological materials: the possible cursory preparations of blanks to facilitate gripping. These preparations could be represented by at least two types: abrasions of the sharpest edges of the blanks (particularly with green bone), which experimentally can sometimes make the retoucher uncomfortable to hold; and preparation of the gripping area of the retoucher by cursory percussion fracture.

USING BONE RETOUCHERS WITH DIFFERENT LITHIC RAW MATERIALS Most experimental programmes about bone retouchers have studied traces left on bone surfaces when working flint implements. Only a few studies have focused on comparing the traces produced by retouching different lithic raw materials (Rosell et al., 2011; Mallye et al., 2012; Mozota, 2013). Such comparative studies have been devoted to distinguishing the traces produced when retouching quartzite blanks from those produced by flint.

There are at least two aspects of this issue of lithic raw materials in which we can significantly expand our current knowledge. The first of these aspects refers to the discrimination of flint and quartzite. I recommend the unification of criteria used by researchers who have addressed this issue, as most of these criteria likely correspond to the same mechanical phenomena and use traces, even if they received different names in each case. In addition, these works only address a single type of flint and a single type of quartzite. For the moment, no study has evaluated the influence of variable properties of the same raw material in the traces of use. For example, it has not been considered how composition or grain size of different types of quartzite or flint can influence the formation of use traces on bone retouchers. Another aspect open to new research is the retouching of quartz, obsidian, silcrete and other raw materials.

LATERALIZATION AND HANDEDNESS The human brain is highly lateralized and this motivates the predominant use of one hand over the other when performing most technical tasks, including retouch. The right hand is typically dominant, even though left-handedness has constituted a low percentage of the population along our evolutionary history (Uomini and Gowlett, 2013). The use of bone retouchers with one specific hand has been documented in different experimental programmes (Rigaud, 1977; Malerba and Giacobini, 2002; Mozota, 2009, 2012). Still, the criteria for identifying this lateralization of retouching tasks are not unified, nor has the subject been deeply explored, especially from an evolutionary and demographic perspective.

Concluding remarks

The review conducted in this work has summarized the historical development of experimental studies on retouchers, in the most general terms. This history can be described as a relatively simple process: researchers accumulated knowledge through their archaeological praxis. This process came together with a progressive development of techniques and methodologies and accelerated with moments of theoretical and methodological innovation. All of these advances allowed for the transition from a qualitative archaeology to alternative approaches that offered more quantitative and verifiable results. Yet, it would be a mistake to think that the most recent works, which provide more information and have a greater explanatory capability, represent more meritorious efforts by recent researchers. As in all fields of science, the most recent works build upon the cascading efforts of previous researchers. Without the first identifications of retouchers in the early years of the 20th century, it would have been impossible to make the first qualitative experiments on retouching lithics with bone; without those studies, it would not have been possible to identify the dozens of assemblages of retouchers that were published since the 1960s; and without that critical mass, researchers of the early 21st century would not have been able to develop their studies to include statistical calculations, which provide greater scientific rigour.

This work has also made it clear that the research potential of retouchers, specifically experimental analysis of retouchers, is promising. There are significant contributions to be made in this area, particularly in support of, or opposition to, recent explanatory models about Palaeolithic human groups. Thus, I want to personally encourage all researchers to address these and other issues in the years to come.

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