# Functional perspectives on lithic standardisation

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## Abstract

Functional data accumulated over the recent decades confirm that tool use mechanics, working edge maintenance, and hafting are important factors determining stone tool form. Yet such data are rarely considered in studies on lithic standardisation, and tool hafting has entered the discussion mostly in the form of untested hypotheses. In this paper, we examine the effects of tool use, resharpening, and hafting on lithic standardisation by drawing on recent use-wear data on Palaeolithic domestic tools and projectiles. We evaluate morphological constraints posed by different tool use tasks and hafting systems, and the effects of these on blank selection. We conclude that the concept of standardisation can be useful in studying lithic assemblage patterning, but it needs to be redefined to accommodate functional variability. We advise shifting the focus from stone tool form to working edge qualities and hafted tool design, which drastically alters the perspective on inter-assemblage variability.

## Keywords

standardisation, lithic use-wear, hafting, blades, tangs, backing

## Introduction

Attempts to understand ancient populations based on material culture have often relied on detailed study of artefact forms and their variation between assemblages. This has led to significant debate about the meaning of tool forms and their ability to inform us about the technological, cognitive, cultural and social capacities of our ancestors (e.g. Binford, 1973; Binford & Binford, 1966; Bisson, 2001; Bordes, 1953, 1967, 1981; Bordes et al., 1972; Bordes & de Sonneville-Bordes, 1970; Chase, 1991; Chazan, 1995; Corbey et al., 2016; Dibble, 1984, 1991; Holloway, 1969; Kohn & Mithen, 1999; McBrearty & Brooks, 2000; Rolland & Dibble, 1990; Semenov, 1964; Wynn, 1988). The origins of the concept of lithic standardisation can be traced back to influential attempts to attribute meaning to stone tool assemblage variability (e.g. Holloway, 1969; Mellars, 1989). Yet, the definition of this concept appears if not vague, at least case-dependent, and analysts' success in identifying standardised forms in the lithic record has been moderate at best. Even though measuring instruments and data processing tools have become more and more sophisticated, the limited availability of data on tool use and hafting and its infrequent exploitation in studies investigating standardisation have produced a situation where functional similarity is not established for tools that are being measured or is only assumed on typological grounds. This overlooks the fact that functional studies have repeatedly demonstrated that tool form and function are poorly correlated (Odell, 1981; Plisson, 2006; Plisson & Beyries, 1998; Semenov, 1964).

Here, we make a first attempt to bring together detailed functional data with frequently used simple measures of standardisation to investigate the links between the two, with a particular focus on the effect of hafting. We first briefly discuss the origins of the concept 'standardisation' in lithic research and its entanglement in debates about human cognition and culture. We establish that the concept is often used but rarely precisely defined, and that attempts to measure standardisation have yielded variable results. We then, by using our recent datasets, proceed to examining how different tool use tasks and working edge maintenance (resharpening) affect tool morphology, and whether stone tool hafting has a notable standardising effect on lithics on the level of blank type, dimensions, or presence of retouch. Hafting has been regularly assumed to drive stone tool standardisation. Recent analyses have drawn particular attention to the effect of retooling (the replacement of worn-out or broken lithic components of hafted tools with fresh ones) on assemblage-level patterning (Kuhn & Shimelmitz, 2022). In these considerations, however, hafting has not been demonstrated for the lithics that were measured but assumed based on chronological affinity with other assemblages reported to contain hafted tools. The present separation of microwear studies interested in hafting and studies geared towards detecting metric or morphological patterning is largely because methods for reliably identifying hafted tools in

archaeological assemblages have been developed only recently (Rots, 2002b, 2010) and require detailed microscopic analysis backed up with experimentation that is more time-intensive than measuring lithics. Data on tool hafting is now becoming increasingly available (de la Peña et al., 2018; Rots, 2002a, 2005, 2009, 2013, 2015; Rots et al., 2011, 2017; Rots & Van Peer, 2006; Taipale, 2020; Taipale et al., 2022; Taipale & Rots, 2020, 2021; A. Tomasso et al., 2018; S. Tomasso, 2021; S. Tomasso et al., 2020; S. Tomasso & Rots, 2018), and provides an opportunity for an initial evaluation of links between stone tool use and hafting and lithic standardisation.

The results of this preliminary investigation suggest that while hafting may produce certain regularities in the lithic record, standardisation would be best approached by looking at particular morphological attributes side by side with functional evidence instead of relying on overall tool form or measures of retouch. We conclude that while the concept of standardisation has value for future lithic studies, it needs to be redefined in a manner that abandons the dualisms on which it was initially based. With our review of the theoretical background of the concept as well as the presently available data on hafted Palaeolithic tools and their metric and technological attributes, we wish to better bridge the knowledge gained in microwear and morphometric studies and encourage future collaborative efforts to the benefit of both.

## What has lithic standardisation been taken to signify?

Stone tool standardisation, i.e. the regularisation of artefact size and form, has been given varied meanings in recent research. Some scholars have viewed it as a signal of higher reliance on composite tools (e.g. Bar-Yosef & Kuhn, 1999) and particularly relevant for retooling (Kuhn & Shimelmitz, 2022). Tightly controlled tool form has also entered discussions on optimisation of technology and risk management, and standardised lithics have been mentioned as beneficial to both reliable and maintainable hafted tool designs (Bleed, 1986; Buchanan et al., 2018; Clarkson et al., 2018; Hiscock et al., 2011; Marks et al., 2001; Nelson, 1991; O'Farrell, 2004). Particularly blades have also been linked to the social aspect of human lives and said to be markers of regional identity reflective of socially transmitted knapping skill (Nelson, 1991). Occurrence of highly similar of stone tool forms over long geographical distances has been claimed to demonstrate inter-group contacts (e.g. Jones & Stewart, 2016; Way et al., 2022; see, however, Dibble, 1989), and standardised blades have been cited as products well-suited for trade (J. E. Clark, 1987; Nelson, 1991). Perhaps the most influential and debated perspective, however, is the view that stone tools with standardised forms reflect the cognitive and symbolic capacities of their makers. Wynn argued that even though a strong link between the development of stone tool technology and the evolution of the human brain is hard to establish, standardised lithic forms

indicate that technology was not entirely ad hoc but involved a level of planning and intellect and might therefore serve as a marker to distinguish human technologies from those used by other primates (Wynn, 1988). Others have gone considerably further and argued that standardised stone tools and the 'imposition of arbitrary form' or 'deliberate design' are indicators of socially shared concepts and may equal the use of symbols and language (Holloway, 1969; McNabb et al., 2004; Mellars, 1989, 1991, 1996). These views were at least partially inspired by Bordes's interpretation of lithic typological variability that he attributed largely to cultural factors (e.g. Bordes, 1953) and have their ties to the debates that followed (e.g. Binford, 1973; Binford & Binford, 1966; Bordes, 1953, 1967, 1981; Bordes et al., 1972; Bordes & de Sonneville-Bordes, 1970; Dibble, 1984, 1991; Semenov, 1964). These perspectives thus connect to the wider discussion on the meaning of lithic assemblage variability.

The language argument was particularly developed in the context of comparing the material culture of anatomically modern humans to that of Neanderthals and other extinct hominins. This line of reasoning maintained that stone tools with distinct shapes reflect 'mental templates' in the minds of their makers, that these types become clearer in tandem with the development of language, and that they ultimately correspond to words (Mellars, 1989). The view that blade-dominated Upper Palaeolithic industries would be more standardised than flake-dominated Middle Palaeolithic industries has been later contested by technological data accumulated in different parts of the world (Marks et al., 2001), and the "fundamental" differences initially observed between Neanderthal and modern human technologies have overall been put into question (see e.g. Villa & Roebroeks, 2014).

The "standardised lithics equal symbols" claim has been further argued against both at conceptual (Chase, 1991) and pragmatic levels (e.g. Dibble, 1989; Marks et al., 2001; Monnier, 2006). Many researchers have pointed out that identifying past mental templates based on lithic assemblages is not simple due to the way lithics change their size and shape through use and resharpening (Dibble, 1987, 1989; Monnier, 2006). Stone tool standardisation has also been rejected as a proxy for human cognition because it can be an outcome of many different circumstances instead of being straightforwardly dictated by mental templates (Chase, 1991; Dibble, 1989; Monnier, 2006). Dibble questioned the link between standardised, regionally varied lithic tool forms and symbol use by arguing that all tool-making animals impose form on the natural environment, making humans non-distinct, and that regional 'styles' in lithic tools can signify systems of social learning but not necessarily use of language (Dibble, 1989). Chase has elaborately argued that arbitrary form in stone tool production is very different from arbitrary giving of meaning to words and that the former is not a proxy for the latter. Further, arguing for the presence of predetermined artefact shapes that can be communicated between individuals necessitates that all other factors affecting

tool morphology (choice of raw material and blank production method, tool function) are controlled for (Chase, 1991).

The concept of ‘standardisation’ evidently cannot be separated from the research historical context where it was most prominently used, i.e. that linked to the origins of modern humans and their cultural capacities. The concept is intertwined with efforts to draw conclusions on the evolution of technology or human cognition based on lithic evidence. It is therefore not independent of certain preconceptions, such as the idea that anatomically modern humans were cognitively and culturally more advanced than their predecessors, or that the lithic record overall should testify to increasing cognitive and linguistic capacities of hominins. As such, the concept is not attitude-neutral, which may partly explain why it is often mentioned but rarely defined with precision.

## How has standardisation been defined, and does it exist?

Some of the most often-cited works that employ stone tool standardisation for the purposes of reconstructing and comparing the cognitive capacities of Palaeolithic people (e.g. Mellars, 1989) do not explicitly define what they mean with the word ‘standardised’ although they appear to refer to lithic end products (finished tools) and their size and shape (Marks et al., 2001). Wynn hinted at symmetry and tool metrics in his discussion and mentions standardised lithics as something that archaeologists encounter time and again at different sites (Wynn, 1988). Already from these early accounts it is clear that some of the problematics of the use of the concept relate to the often-obscure limit between what is in the eye of the beholder (the present-day archaeologist) and what was in the mind of the prehistoric stone tool maker.

To counteract these problems, later works have attempted more precise definitions of standardisation. Marks et al. (2001) have described a standardised product as something that presents “low variability in characteristics that define [it]”. They and other workers have formally investigated stone tool standardisation using different criteria, including typological diversity, blank selection (Chazan, 1995; Marks et al., 2001), number of scars on flaking products (Schlanger, 1996), position and type of retouch (Dibble, 1989; Marks et al., 2001; McNabb et al., 2004; Monnier, 2006; Wierer, 2013), symmetry (McNabb et al., 2004; Monnier, 2006), outline shape, and patterning in manufacture (McNabb et al., 2004). Some of the criteria, such as the third on Monnier’s list (“The location of retouch is similar, and there is a clear separation between retouched and un-retouched portions of the tool”)(Monnier, 2006), are rather industry-specific and not applicable to e.g. bifacially shaped tools. Metric attributes feature prominently in lithic standardisation studies and include length, width, thickness, and sometimes their ratios and

derivatives, such as surface area (Chazan, 1995; Dibble, 1989; Kuhn & Schimelmitz, 2022; Marks et al., 2001; Monnier, 2006; Montoya, 2002; Schlanger, 1996; Wierer, 2013).

Recent years have seen the application of geometric morphometric approaches to achieve more detailed outline (e.g. Buchanan et al., 2018; Hoggard et al., 2019; Iovita & McPherron, 2011) or three-dimensional data (e.g. Archer & Braun, 2010) on tool shape. These analyses have often been combined with traditional tool metrics.

Using their selected attributes and approaches, investigators have managed to detect standardisation to varying degrees. Dibble found no evidence of Levallois flakes being more standardised than bifacial shaping flakes, the latter of which are hard to perceive as “desired end products” (Dibble, 1989), whereas Schlanger, based on the analysis of flakes from a single refitted core, claimed that Levallois flakes could be distinguished from the rest of the products (Schlanger, 1996). Diachronic comparisons have often failed to find consistent evidence of increasing standardisation over time, although some other patterns have emerged (e.g. Chazan, 1995; Hoggard et al., 2019; Iovita & McPherron, 2011; Marks et al., 2001; McNabb et al., 2004; Monnier, 2006). Significant exceptions to this rule include the recent large-scale comparison of blade and bladelet metrics by Kuhn and Shimelmitz who found increasing standardisation in the global record, largely driven by the introduction of pressure blade technologies (Kuhn and Shimelmitz, 2022) and Buchanan et al.’s study on Clovis and Folsom points that showed that the younger Folsom points are more standardised (Buchanan et al., 2018).

Critical examination of past use of simple tool metrics (e.g. length-width ratio) in measuring standardisation has shown that such measures can be misleading if not examined against constraints posed by lithic raw materials and fracture mechanics and classification criteria used in defining stone tool types to be studied (Dibble, 1989). Overall artefact shape has likewise been questioned to have universal significance in the analysis of lithic standardisation. The concept of mental template was initially based on artefacts *for which overall morphology matters*, for instance pottery, whereas real-life stone tool users may often be far more concerned with working edge qualities than general artefact morphology (Monnier, 2006). While the shape of ceramic vessels can be modified up to an extent for stylistic or signalling purposes, this is much less frequently the case with stone tools. In their discussion on Acheulean bifacial tools, Archer and Braun note that consensus as to what would be the behaviourally relevant morphological variables to measure is generally lacking (Archer & Braun, 2010).

In brief, even though the analytical tools for addressing certain aspects of morphological variability and standardisation are in place, linking the resulting data to past human behaviour in a meaningful manner remains a challenge, and the ability of standardised lithics to speak for past cognitive and cultural capacities has been questioned by many. A problem identified by several

researchers (e.g. Chase, 1991; Monnier, 2006) is the difficulty of knowing to what extent tool form is dictated by pragmatic aspects of tool production and use, such as raw material constraints, functional demands, and working edge maintenance, and to what extent it could reflect cultural norms. While the issue has been identified by many, the simplest solution, that of examining tool morphology and dimensions against detailed functional data, has rarely – if ever – been implemented.

## Functional perspectives to standardisation

We explore in this section the ways in which tool use, maintenance, and hafting affect the morphology of lithics and their possible standardisation. We discuss these in the form of cautionary tales. Our archaeological case studies include projectiles and domestic tools from the Recent and Final Gravettian occupations at Abri Pataud (Dordogne, France), dated to c. 24,000 BP and 22,000 BP, respectively (Bricker, 1995; Chiotti et al., 2015; Douka et al., 2020; Movius, 1975, 1977; Nespoulet et al., 2013), and from the Early Gravettian occupation of Maisières-Canal (Belgium) (28,000 BP) (de Heinzelin, 1973; Haesaerts & Damblon, 2004; Jacobi et al., 2010). We compare these data with earlier results from the Magdalenian site Verberie, dated to between 12,950 and 12,430 BP (Enloe & Audouze, 2010), from Level N2b at the Middle Palaeolithic site of Bettencourt, dated to around 75–85 ka by TLIRSL on sediment and ESR on teeth (Antoine et al., 2002), and from Level IIA at the Middle Palaeolithic site Biache-Saint-Vaast, dated by ESR to 253 +53/-37 ka (Guipert et al., 2011) We further contextualise them by making use of published data on assemblages from varied geographical and chronological contexts.

Our datasets were collected using an established, experiment-based methodology for identifying hafted and hand-held stone tools, detailed in previous publications (e.g. Rots, 2002b, 2003, 2010; Rots et al., 2006). The method combines observations made using different magnifications and lighting techniques (stereomicroscope with oblique lighting at magnifications <100×, metallurgical incident light microscope at magnifications of 100–500×) that are combined into a pattern, a strategy that blind tests have demonstrated to yield the most reliable results (Rots et al., 2006). Postdepositional surface alterations were dealt with by analysing large samples of lithics from the same archaeological context to gain a good view of taphonomic wear affecting each sub-assemblage and by limiting the analysis to low magnification (stereomicroscope) in the case of insufficiently preserved surface wear. For the purposes of the present study, the datasets that are discussed in detail are narrowed down to the artefacts that allowed determining the prehensile mode (hafted vs hand-held) with the highest level of certainty, i.e. to sufficiently preserved artefacts with explicit wear patterns. While different hafting arrangements and haft raw materials

produce distinct wear patterns in the non-active parts of the stone tool and can be identified with the help of experimental archaeology and comparative analysis when the wear is sufficiently developed (for details, see e.g. Rots, 2002a, 2002 bright spots, 2008 animal materials, 2010; Rots et al., 2006), we limit the discussion here mostly to presence/absence of hafting and broad categories of handle designs.

Stone tool shape and size can be affected by various factors, among which are raw material qualities and the size and shape of nodules and blanks (e.g. Archer & Braun, 2010; Bordes et al., 1972; Chase, 1991; Dibble, 1991; Kuhn, 1992; Marks et al., 2001; White, 1998). Blank attributes are affected by knapping method and technique as well as knapper skill (Finlay, 2008; Klaric, 2018; Kuhn & Shimelmitz, 2022; Lassen & Williams, 2015; Marks et al., 2001; Montoya, 2022; Muller et al., 2022; Nonaka et al., 2010; Pelegrin, 2021; Pigeot, 1987; Sternke & Sørensen, 2009). Decisions made about blank production, selection, and tool shaping reflect functional demands dictated by the tasks the tools were made for and whether they were meant to be used hand-held or hafted. Stone tool life cycles including resharpening (see Dibble, 1984, 1987, 1989, 1991, 1995; Frison, 1968; Shott & Weedman, 2007) are equally important determinants of tool morphology at discard.

### *Tool use sets demands on tool morphology*

Given that most stone tools are functional objects made for a practical purpose, their morphology is controlled by requirements related to their use and prehension or hafting. Recurrency of different tasks can be expected to result in morphological patterning in the lithic record. Approaches focusing on overall shape of formal tools have yielded conclusions including that of Monnier's that some morphologically constrained tool types such as perforators could correspond to mental templates better than the remaining categories (Monnier, 2006). This statement acknowledges an important aspect of lithic assemblage variability, namely that some tasks impose more distinct shapes on stone tools than others. Nevertheless, there are limited grounds to argue that e.g. cleavers would be any less adapted (designed) for a particular task or tasks than perforators; the characterisation of their active edges would simply require an approach that does not rely on measures of retouch, as their design typically exploits a naturally acute-angled and regular edge of a flake.

The link between working edge morphology and overall tool shape is a complex matter, and relatively little addressed in lithic studies. Iovita and McPherron's discussion of Lower and Middle Palaeolithic bifaces is valuable in this respect, as it proposes that the overall shape of a biface may be a by-product of the creation of suitable working edges within the limits of fracture

mechanical possibilities, and therefore a secondary or misleading variable to examine when measuring standardisation (Iovita & McPherron, 2011). Nicoud's large-scale analysis of Acheulean bifaces from western Europe could show that superficially similar artefacts can represent differential strategies in managing working edges vs overall tool shape (e.g. Nicoud, 2013). In the context of less formal industries, study of the selection of unmodified quartz flakes for tools has shown that systematic selection did take place at prehistoric knapping sites largely based on edge qualities and blank completeness or volume rather than blank shape (Knutsson et al., 2015; Rankama, 2002). Consequently, an overemphasis on general tool morphology can produce misleading data and fail to detect consistency and repetition in functionally relevant attributes on assemblage scale.

The functional data we have collected so far has revealed some such patterning. We have noted, for instance, that butchering knives often share features across different time periods. At both Middle Palaeolithic sites such as Biache-St-Vaast and Bettencourt (Rots, 2015) and Upper Palaeolithic sites like Maisières-Canal (Taipale & Rots, 2021), butchering knives are frequently pointed and somewhat asymmetrical, combining a curved and straight working edge (**Figure 1**). Such universal preferences may lead to partial convergence in lithic assemblages that otherwise have little in common (for a broader perspective on the question, see e.g. L-G l'homme et la matière 30-36; milieu et technique 336-340). The desired distal tool morphology can be achieved either by simply selecting a blank with suitable attributes, or by applying retouch with varying characteristics.

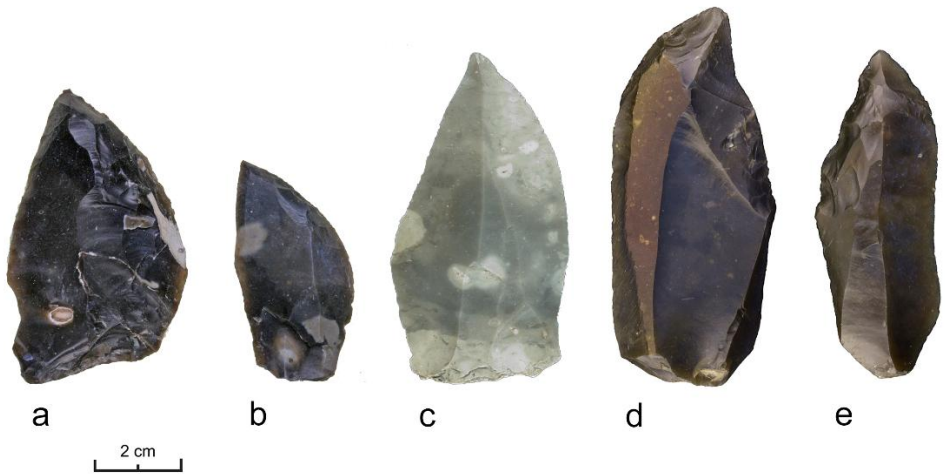


***Figure 1****. Dorsal views of morphologies of the active parts of Middle and Upper Palaeolithic butchering knives. a-b: Biache-Saint-Vaast* (Rots, 2013, 2015)*, c: Bettencourt* (Rots, 2015)*, d-e: Maisières-Canal* (Taipale & Rots, 2021)*.*

A similar case could be made for projectiles. Projectiles mounted on the apex of a shaft need to share a sharp tip and one or two cutting edges, though variation may exist in how this general morphology is obtained (e.g. unifacial versus bifacial flaking). In the case of composite points, functionality is achieved by creating cutting edges that combine an organic point with laterally and sometimes distally hafted lithic insets (see e.g. Gaillard et al., 2015; O'Farrell, 1996; Pétillon et al., 2011; A. Tomasso et al., 2018). Morphology and size of armatures need to be adapted to the raw material, hafting system, shaft weight and dimensions, weapon delivery system, prey choice, and hunting conditions (see e.g. Cattelain, 1997; Coppe, 2020; Coppe et al., 2019, 2022; Ellis, 1997; Friis-Hansen, 1990; Knecht, 1997; Pétillon et al., 2011; Taipale et al., 2022), potentially leading to standardisation in situations where the key variables are held constant. The final shape of armatures can be variably achieved through debitage strategies or secondary modifications (Klaric, 2006; Klaric et al., 2009). Within individual industries, the quantity and attributes of retouch can be adjusted according to the initial shape of the tool blank (Montoya, 2002). The extent to which the full variability observed in the lithic projectile record is linked to differences in hafting and details of use is currently unknown.

Of the rare case studies we have cited here that have found evidence of tool standardisation over time by looking at shape and size attributes, Buchanan et al.'s results indicate that Folsom points are more standardised than older Clovis points. Relying on functional interpretations proposed by other researchers, they explain the higher uniformity of Folsom points by functional specialisation (with Clovis points viewed as multifunctional and Folsom points as exclusively hunting weapon tips) as well as morphological constraints imposed by preparations for fluting that was developed further in the Folsom industry than in the preceding Clovis (Buchanan et al., 2018). In the European Upper Palaeolithic, backed points have been cited as standardised (Wierer, 2013). Compared to Folsom points, however, Gravette and microgravette points may present enough uniformity in shaping to make up a tool category easily recognised by typologists, but they may be less standardised in their dimensions even within a single site (see e.g. Bricker & David, 1984, 1995; Cormarèche, 2020; Nespoulet, 1996, 2000). The Folsom example (Buchanan et al., 2018) shows that the best strategy in assigning meaning to armature size and shape is a careful consideration of the combined effect of knapping technological and functional variables.

Also hide scraping tools often show high similarity in their active parts. In contrast to knives or projectiles, these tools need to have more obtuse, convex edges to avoid cutting the hide. The exact mechanical requirements depend on the stage of hide processing. This implies that the active part will mainly respond to functional constraints and show regularity over time.

Other functional categories, by contrast, may show greater variability in functional requirements. Woodworking is a good example as it may cover tasks ranging from percussion activities for wood

procurement to various processing activities to very precise craft activities. The edge morphologies and general shapes of the tools used in each of these tasks may thus differ significantly.

Data on Recent and Final Gravettian tools from Abri Pataud used for working hard animal-derived materials (bone, antler, ivory) indicate that the main use gesture can determine the morphology of the active part. Grooving tools display acuter bit angles, whereas tools used in transverse motion tend towards obtuse or non-restricted angles (Taipale 2020). Bit angle is irrelevant for functionality in the latter case, although it might affect prehension. Significantly, the absolute range of bit angles varies between industries at Abri Pataud, with acuter angles observed in the Final Gravettian sample (Taipale, 2020, figs. 8.23, 8.24). This might be explained by a combination of task requirements and choices made about blank production and tool shaping. Therefore, while certain measurements, such as those describing edge shapes and angles, can be tied to tool use, several variables need to be considered to arrive at reliable interpretations.

Edge shapes and angles were explicitly considered and measured by use-wear analysts during the early decades of the development of the method (e.g. Kamminga, 1982; Moss, 1983) and continue to be reported in functional studies (Macdonald et al., 2020 and references therein). Nevertheless, the measuring of tool shape is largely developed outside the field of functional studies, and the two aspects are seldom connected. We acknowledge this as an important weakness of present approaches. Morphometric investigations informed by functional data could aid in isolating relevant metric variables and help us better understand deliberate control of stone tool form by prehistoric knappers.

***Resharpening in view of continued use determines morphology at discard***

Stone tool morphology is initially determined by knapper choice and raw material constraints, but in prolonged use is affected by cycles of resharpening (Frison, 1968) and ultimately depends on the stage and reason of discard (Dibble, 1987; Rolland & Dibble, 1990). This view has been incorporated in explanations of assemblage variability (Iovita, 2011; McCall & Thomas, 2012; Soriano et al., 2015), but in most cases remains to be confirmed by functional data. Tomasso et al's study of Aterian points (S. Tomasso, 2021; S. Tomasso & Rots, 2018), for instance, found no evidence of frequent resharpening of points in contrast to the model proposed by Iovita (2011). The available studies focused on particular functional categories demonstrate the power of the functional approach in explaining tool shape. In the case of hide scrapers recovered at Verberie, the irregular active edge morphologies could be linked to incomplete resharpening (Rots, 2005). Corresponding observations have been made for butchering knives from Maisières-Canal, where

tools discarded as the result of failed resharpening can present ragged distal edge lines (Taipale, 2020, p. 12-14 in Appendix 4; Taipale & Rots, 2021, fig. S4). Elsewhere, variations in scraper working edge convexity have been explained by the proximity of haft limit on resharpened tools (Jardón Giner & Sacchi, 1994). Continued resharpening of tools like burins may sometimes lead to an increase in their morphological and typological variation (e.g. Buisson, 1991; Nespoulet, 2000; Taipale, 2020, p. 99).

These examples show that tool use data can be an important asset to researchers looking into standardisation, as functional results enable the analyst to regroup lithic tools into categories that are comparable in terms of tool function, hafting status, and discard stage. Such comparability is necessary for drawing informed conclusions about standardisation of tool form. The existing models of reduction continuums as determinants of assemblage variability may well hold some truth in them, but they could be tested and strengthened by functional data. This again calls for better bridging of use-wear studies and approaches interested in morphological variability.

***One raw material is not the other***

Factors related to raw material economy can affect standardisation of size and shape of tools, as the replicability of tool forms and the knapper's ability to extend their use-lives depends on the fracturing qualities of the lithic raw material. Quartz industries are a case in point. The fracture mechanical properties of quartz differ significantly from those of e.g. flint, which has led to prehistoric quartz assemblages with a high frequency of fragmentary flakes and low counts of easily identifiable, elaborate formal tools (see e.g. Callahan et al., 1992; de Lombera-Hermida & Rodríguez-Rellán, 2016; de Lombera Hermida, 2009; Domanski et al., 1994; Driscoll, 2010, 2011b, 2011a; Lindgren, 1998; Manninen, 2016; Manninen & Knutsson, 2011; Manninen & Tallavaara, 2011; Mourre, 1996; Rankama, 2002; Rodríguez-Rellán, 2016; Tallavaara et al., 2010; Tardy et al., 2016). Prehistoric tool makers found ways to cope with the relatively unpredictable behaviour of quartz under hammer impact (see e.g. Knutsson et al., 2015; Manninen, 2016; Rankama, 2002), and lithic technologies were adapted to raw material situation through different strategies. Use of quartz sometimes clearly lowered the level of lithic standardisation. An example is the Early Mesolithic composite point technology in northern Fennoscandia where hunter-gatherers maintained the overall tool design by replacing formal flint blade/bladelet inserts with informal quartz flakes when migrating into areas where only quartz was abundantly available (Knutsson et al., 2015, 2016). In other contexts in the same region, however, lithic tool technology and form were conserved regardless of raw material constraints. This is the case for bifacial pressure flaking that was applied on quartz contemporaneously with the Comb Ware flint import and again with the introduction of the straight-based arrowhead in the Early

Metal Age (Rankama et al., 2006). Such occurrences show that tool form is sometimes rigidly transferred onto a new raw material, whereas in other cases formal constraints are relaxed to facilitate production. Lithic artefact standardisation can therefore be considered raw material dependent to a degree that varied according to the ecological and socio-economic context of lithic tool production.

In industries where stone tool raw materials that allow limited control over the fracturing process dominate, investigation of tool standardisation should turn the focus to entire hafted or composite tools instead of their lithic components to understand design concepts and their rigidity, i.e. standardisation. The degree to which raw material choice may have been linked with particular planned tool shapes and functions remains under-investigated especially in Palaeolithic archaeology.

### *The assumed link between blades and hafting*

Blades are usually perceived as predictable and regular in shape and are therefore often cited as standardised flaking products. They have been argued to reflect increased reliance on hafting and composite tools (e.g. Bar-Yosef & Kuhn, 1999; Kuhn & Shimelmitz, 2022). Within blade industries, the introduction of soft hammer and indirect percussion techniques in the Upper Palaeolithic resulted in higher control over blank morphology that has been said to have facilitated the production of replacement parts for composite tools (Bar-Yosef & Kuhn, 1999), although it appears that only the later adoption of pressure techniques in blank production had a significant standardising effect on blank metrics on assemblage scale (Kuhn & Shimelmitz, 2022).

Currently available functional data make it obvious that hafting predates blade-based industries, with dates for the earliest evidence of hafting being as old as 250ka in Europe (Rots, 2013) and 200ka in Africa (Rots et al., 2011; Rots & Van Peer, 2006). The frequency of hafted stone tools at different Middle Palaeolithic and Middle Stone Age sites also shows that hafting was already well-embedded in technology (de la Peña et al., 2018; Rots, 2013, 2015; Rots et al., 2011, 2017, 2021; Rots & Plisson, 2014; S. Tomasso, 2021; S. Tomasso & Rots, 2018). While the Upper Palaeolithic record contains evidence of hafted blade tools, including those used in craft activities (Rots, 2002b, 2002a, 2005), the link between blades and hafting has not yet been tested on a large scale using microwear evidence.

As an example, we compared the presence of blades versus flakes among hafted and hand-held tools in a sample of Recent Gravettian scrapers from Abri Pataud, all used in hide working, to examine whether hafting affected blank choice. The scrapers are all made of fine-grained flint of local or regional origin (Nespoulet, 1996). A significant feature of the Level 3 scraper assemblage

(n=231) is the use of both flakes and blades as tool blanks (**Figure 2**), among which blades slightly dominate (Nespoulet, 1996; Taipale, 2020). We selected a sample of 47 scrapers for a detailed functional study relying mostly on low magnification observation (Taipale, 2020) (**Figure 3**). Here, we discuss the artefacts for which prehensile mode (hafted vs handheld) could be determined with relative certainty (n=25).


***Figure 2****. Scrapers on flakes and blades from Abri Pataud Level 3 (Recent Gravettian, c. 24,000 BP).*

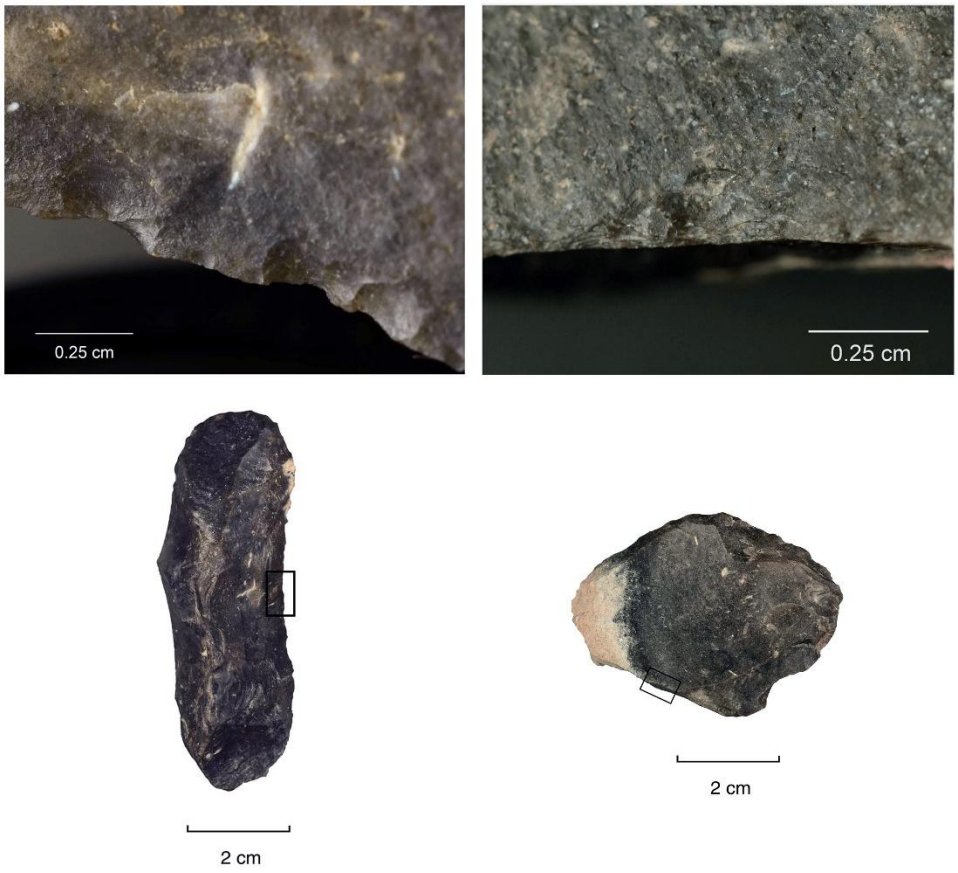


***Figure 3****. Haft scarring on a blade scraper (AP/58-3-16) and a flake scraper (AP/59-3-1945) from Pataud Level 3* (Taipale, 2020)*.*

Both flakes (n=7) and blades (n=6) were used as blanks for tools identified as hafted and possibly hafted in our sample, but the proportion of blades (n=2) appears to drop in the group of tools showing no evidence of hafting and flakes are overrepresented (n=10). Larger samples would clearly be needed to test the validity of these observations, but the link between blades and hafting is worth considering.

If we integrate other available datasets, burins from Maisières-Canal that were used dominantly for grooving and perforating tasks on hard animal material (Taipale, 2020; Taipale & Rots, 2020) suggest that the frequency of blades does not straightforwardly reflect the frequency of hafting. This Early Gravettian site has a blade-dominated lithic industry (see Touzé, 2019) enabled by high-quality flint that was abundantly available in the vicinity of the site (de Heinzelin, 1973; Moreau et al., 2013, 2016; Otte, 1979; Pesesse & Flas, 2012; Touzé, 2019). In the typo-technological category of burins (n=382), 85% are made on blades (Touzé, 2019).

We analysed a sample of 50 formal burins made on raw blades or recycled from tools or preforms that were themselves made on blades. The proportion of hafted and possibly hafted tools, as opposed to ones bearing no evidence of hafting, is relatively low (15 against 35 artefacts, respectively), and even lower if burins with an obvious tang (see Rots, 2002a) (n=11) are excluded from the sample (6 versus 33 artefacts). Blades were widely selected for handheld tools, which casts doubt on the link between blades and hafting among tools used for working osseous material.

When the examination is extended to other tool categories, projectiles, knives, and hide scraping tools all represent exclusively or dominantly hafted tools at Maisières-Canal (Coppe, 2020; Rots, 2002b; Taipale, 2020; Taipale & Rots, 2020, 2021) and were likewise made on blades. Did these tools hold priority in decisions about blank production, and were burins a category of secondary importance in comparison? Burins (n=382; Touzé, 2019) clearly outnumber endscrapers (n=44; Touzé, 2019) as well as points and point fragments (n=197; Touzé, 2019), which include both projectiles and knives (Coppe, 2020; Rots, 2002b; Taipale, 2020; Taipale & Rots, 2021). On the other hand, knives and scrapers that were generally used on soft materials may well have had longer use-lives than tools employed in crafts involving bone, antler and/or ivory. Comparing the absolute numbers of tools may therefore not be the best way to estimate which of them held priority in decisions about blank production (cf. Taipale, 2020). The combined need to produce projectiles, knives, and scraping tools may have weighed in heavily when choosing core reduction strategies.

Further, the relative ease of shaping a blade into a dihedral burin, the dominant typological category at the site (Touzé, 2018), could be a possible incentive to opt for blades even in the case of hand-held tools. Same applies to resharpening, as blades allow maintaining acute bit angles while providing enough length for prolonged use. Frequent resharpening is demonstrated by our data (Taipale & Rots, 2020), with an average of 2.1 spalls removed per burin facet in a sample of burins (n=79). Blades can also be imagined to make comfortable hand-held tools thanks to their elongated morphology. There were therefore incentives to integrate the production of burin blanks in blade production sequences, and no apparent downsides to such a choice considering the large nodules of fine-grained flint available locally.

These case studies show that the role of blades in Upper Palaeolithic industries and their links to hafting are best understood when entire toolkits are evaluated. Klaric et al.'s analysis of Middle Gravettian material from Brassempouy established that the production of blanks for armatures was embedded in sequences that also yielded blanks for domestic tools, but with a tendency of projectile blanks coming from more regular cores (Klaric et al., 2009). Bar-Yosef and Kuhn proposed that skills and habits acquired in producing insets for composite tools might "bleed over"

into other production sequences so that uniform blanks (blades) could be found also in other tool classes, including hand-held tools that do not require such uniformity (Bar-Yosef & Kuhn, 1999). Our functional data adds two important perspectives to these considerations. First, hafting is not the only reason to favour elongated, relatively regular tool blanks, as demonstrated by the hand-held burins at Maisières. Second, hierarchical relationships between stone tool categories can only be established when enough functional data is available. This includes knowledge about resharpening, length of tool use-lives, and details of their hafting.

In our archaeological cases, a high frequency of blades within a tool category is by itself not enough to infer hafting. Neither should flake tools be viewed as hand-held implements. Nevertheless, a link between blade-based technology and high rates of hafting can be proposed and should be tested through further analyses.

***Hafting affects stone tool morphology*** Hafting a tool demands an additional time investment, but it may increase the tool's effectiveness. The choice to haft a stone tool may depend on site function and the frequency of a task (Rots 2015). Hafting strongly influences the status of a stone tool because the use life of a handle is much longer than that of a replaceable stone edge. Ethnographic accounts demonstrate that handles are generally intended to accommodate different stone tools throughout their use life and that handles are often inherited from one generation upon the next (Rots & Williamson, 2004). Stone tool forms are therefore expected to be adapted to a handle instead of the opposite, and explanations on the appearance of certain morphological innovations consequently need to take hafting into account (Rots, 2003). For the same reason, retooling and its frequency need to be considered in explaining lithic assemblage variability (Kuhn and Shimelmitz, 2022).

The hafted parts of tools are constrained by the mechanical demands set by the intended tool use. This factor is often overlooked, and hafting is instead viewed as affecting tools equally. Yet hafting a projectile sets other requirements on the hafting arrangement than hafting a cutting implement or a scraping tool. A projectile, or any other tool used in tasks involving impact (e.g., percussion, digging), necessitates that the stone tool-haft combination absorbs the shock unless fracture of the lithic at the haft limit is a preferred outcome to preserve the shaft (Akerman, 1978; Akerman et al., 2002; Rots et al., 2020). The degree to which the shaft or handle absorbs the shock determines how much energy is transferred onto the stone tool. This sets minimum requirements for its width, thickness, and cross-section.

Whereas projectiles fracture due to the combined effect of bending and compression, in scraping tasks resistance to flexion is the main factor to consider, while for cutting tasks, resistance to

shearing is important. Perforating or drilling tasks generally set little demands on the hafting system as long as the stone tool is firmly fixed in the handle. In such use contexts, the demands on stone tool form depend on the chosen handle design.

Different haft designs set different demands on stone tool morphology. Certain handle types and materials and certain fixing agents permit more variation in stone tool size and morphology than others and are thus less prone to contribute to highly standardised tool forms. Male hafts in which the stone tool is inserted are generally the most restrictive on the level of stone tool morphology. The insertion of a lithic tool in medullary cavity in bone or in the spongiosa in antler haft requires a tanged morphology or at least reduction of the width of the hafted extremity (cf. Rots, 2002a, 2005), while juxtaposed hafts generally permit more morphological variation (for haft terminology, see Rots, 2010; Stordeur, 1987). The use of glues may accommodate some shape variation by filling in voids, while bindings are flexible and adapt to a range of morphologies, although blunting of the stone tool edges by retouch may be necessary to prevent bindings from being cut during tool use. Which hafting materials are available and useful depends on the environment and climatic conditions, while their choice depends on technical constraints and cultural preferences.

To understand morphological variability, analysts need to be able to distinguish between the active and the non-active part of the lithic implement and bear in mind the difference between the stone tool and the complete hafted or composite tool. Some recent studies on standardisation have attempted to isolate the active part of the tool by considering tip shapes in addition to overall morphology (McNabb et al., 2004) or by examining tips and basal portions of the tool separately (Buchanan et al., 2018; Iovita & McPherron, 2011). In these cases, however, the distinction was made on morphological grounds without reference to use-wear data, and it therefore remains speculative. Moreover, most of the case studies we have cited here have focused on measuring the dimensions and comparing the outlines of entire tools. Hafting wear analysis allows determining the location of haft limit on a stone tool, and reliable results can be achieved with sufficient training and construction of experimental reference collections (Rots, 2010; Rots et al., 2006). This potential remains to be exploited in standardisation studies.

Gravettian domestic tools have been mentioned as less constrained in size and shape compared to projectiles by some (Wierer, 2013), but the effect of hafting on the shape and size of Upper Palaeolithic domestic tools is only beginning to be addressed (Rots, 2002a, 2005). As an initial test on a previously unstudied assemblage, we examined the maximum dimensions of hafted and hand-held scrapers from Pataud Level 3 (n=25).

The average lengths of hafted vs unhafted intact scrapers are nearly identical (**Figure 4**, **Table 1**). Hafted scrapers appear to be both narrower and thinner than unhafted ones when mean values are examined. The two measures are clearly interdependent. Despite being potentially smaller-

sized, the hafted scrapers cannot be said to be more standardised if the coefficient of variation is used as a measure of metric variability (cf. e.g. Archer & Braun, 2010; Dibble, 1989; Hoggard et al., 2019; Kuhn & Shimelmitz, 2022; Marks et al., 2001; Monnier, 2006) – none of the differences observed in the present sample are statistically significant (**Table 1**). The evidence of hafting on both endscrapers on blades and on scrapers on flakes with a circular or oval final morphology suggests that the morphological variability is linked to different handle designs in use at the site during the Level 3 occupations (Taipale, 2020). This means that an increase in the number of available haft designs may lead to a decrease in standardisation.

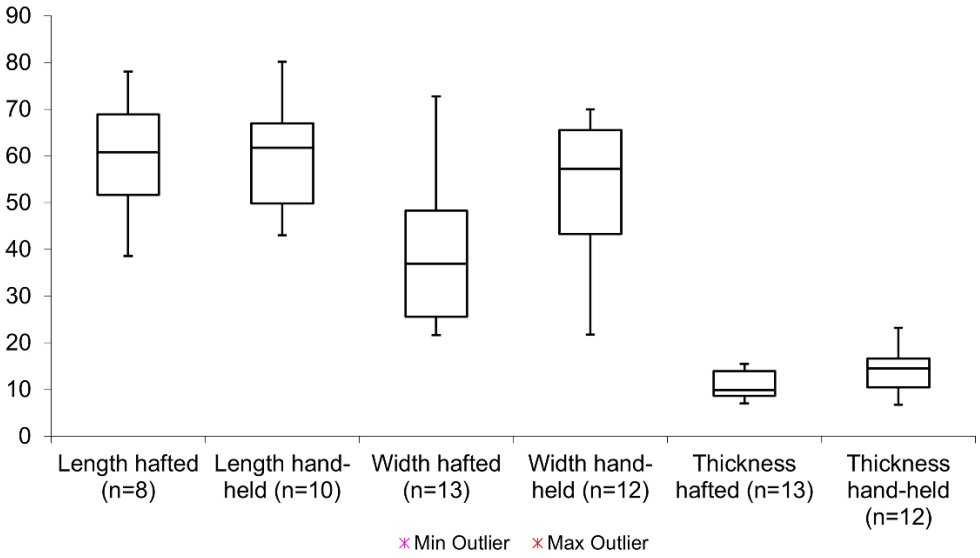


***Figure 4**. Maximum dimensions (in mm) of Abri Pataud Level 3 hide scrapers (n=25). Length measured only for intact pieces.*

| Abri Pataud Level 3 scrapers | Hafted and possibly hafted (n=13) | Hand-held and no evidence (n=12) | p value |
|---|---|---|---|
| Length intact mean | 59.91 | 59.75 | |
| Length intact STDEV | 12.81 | 11.13 | |
| Length intact CV | 0.21 | 0.19 | 0.692 |
| Width all mean | 39.46 | 53.50 | |
| Width all STDEV | 15.09 | 14.68 | |
| Width all CV | 0.38 | 0.27 | 0.327 |
| Thickness all mean | 11.08 | 14.22 | |
| Thickness all STDEV | 2.96 | 5.18 | |
| Thickness all CV | 0.27 | 0.36 | 0.342 |
| Length/width intact mean | 1.40 | 1.39 | |

| | | | |
|---|---|---|---|
| Length/width intact STDEV | 0.67 | 0.75 | |
| Length/width intact CV | 0.48 | 0.54 | 0.821 |
| Width/thickness all mean | 3.63 | 4.13 | |
| Width/thickness all STDEV | 1.13 | 1.66 | |
| Width/thickness all CV | 0.31 | 0.40 | 0.439 |

572 ***Table 1****. Tool metrics (in mm) for Abri Pataud Level 3 scrapers (n=25) (CV=coefficient of*
573 *variation).*

574 The clearest signal given by the scraper metrics concerns the maximum thickness of hafted
575 scrapers. While the samples of hafted vs unhafted tools largely overlap (**Figure 5**), hafted
576 scrapers have an upper limit of thickness at around 15mm. The lower limit slightly above 6mm,
577 on the other hand, seems to be the same for both and is probably determined by task
578 requirements, including resistance to bending breaks. The lower limit perfectly corresponds to
579 that established in large-scale hafting experiments, where fractures at haft limit occurred more
580 frequently for thicknesses equal to or below 6mm when scrapers were used in adzing, chiselling,
581 or scraping (Rots, 2010). If the 15mm upper limit observed at Pataud could be confirmed by larger
582 samples, hafted scrapers could be said to be more standardised in the sense that they cannot
583 exceed a certain thickness. This has implications for blank production and/or selection. Thickness
584 has been cited as the dimension that is the most difficult to adjust through secondary modifications
585 and that is also challenging to control by core preparation and indenter choice when blanks are
586 produced by percussion (vs pressure) (e.g. Kuhn and Shimelmitz, 2022; Montoya, 2002). This
587 makes the observed strict upper limit to scraper thickness at Pataud even more significant. Given
588 the considerable morphological variation of Level 3 scrapers (**Figure 2**) consistent with co-
589 existence of different handle designs, the 15mm upper limit does not appear to only reflect
590 constraints related to retooling, i.e. fitting fresh lithic bits to existing handles (cf. Kuhn &
591 Shimelmitz, 2022), but is rather an overall maximum thickness set for *any* hafted hide scraper.

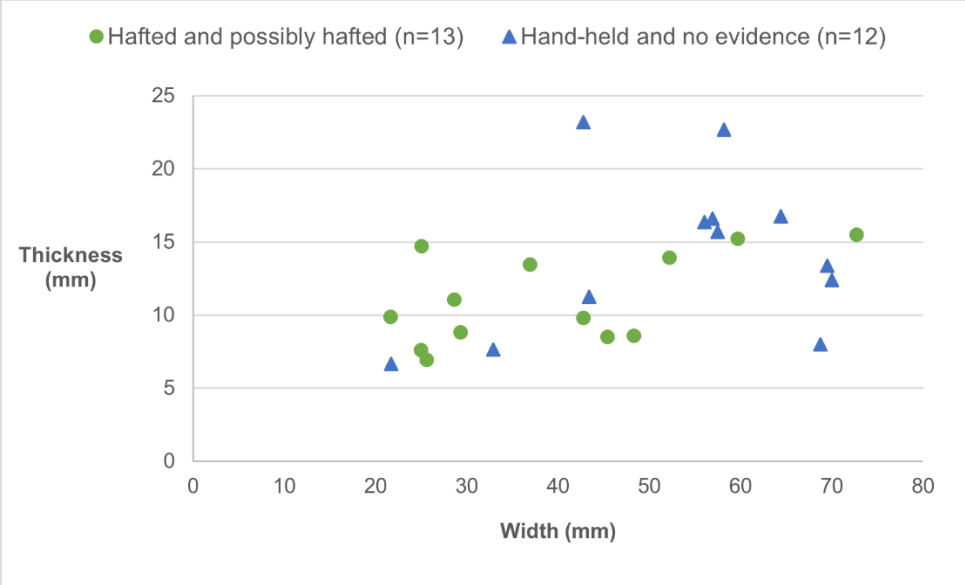


***Figure 5****. Width and thickness of hafted and hand-held scrapers from Abri Pataud Level 3 (n=25)* (Taipale, 2020).

Our investigation of retouch patterns on hand-held versus hafted hide scrapers revealed no clear pattern. Importantly, many hafted tools we have identified thus far do not show secondary modifications in their non-active parts (Taipale, 2020; Taipale & Rots, 2020, 2021). The presence and position of retouch (absent/unilateral/bilateral) in the sample is affected by variability in handle designs and probably stone tool life cycles, including recycling. In several UP site contexts, retouch on lateral edges of tools such as scrapers and burins has been found to relate to an earlier stage of use, often as knife (Taipale, 2020). In some cases, however, lateral retouch on scrapers is clearly linked with hafting: the hide working scrapers of the Magdalenian site of Verberie (France) have lateral retouch only in cases where the tool width needed to be reduced to permit insertion into a handle made of hard animal material (Rots 2005). These results advise detailed reconstruction of stone tool life cycles and hafting systems to fully understand retouch patterns.

Besides the elongation, width, and regularity of blank outline, profile curvature can interfere with hafting and may therefore be avoided in blank production or selection, or later eliminated by retouch (see e.g. Rots, 2005). While a connection between hafting and stone tools straight in profile can therefore be imagined, at Maisières-Canal curved blanks were sometimes selected for hafted hide-working tools and the effect of blank curvature was mitigated by orienting the tool in the handle so that the straighter extremity was hafted (Taipale & Rots, 2020). On projectiles, blank curvature was dealt with by preparing a tang and fixing it in a split shaft (Coppe, 2020; Taipale et al., 2017). The latter example shows that even though projectile points are often made on blanks

615 that tend towards regularity and uniformity (Klaric et al., 2009; Wierer, 2013), this is not the case
616 universally. Instead, constraints posed by undesirable blank characteristics can be overcome by
617 adapting the hafting system.

618 In sum, the effect of hafting on tool morphology and secondary modifications is variable and
619 dependent on intended tool use and haft design.

620

621 ***Tangs, backs, and hafting***

622 Tanged tools are an artefact category that has long been associated with hafting (e.g. J. D. Clark,
623 1970; Marchand & Aymé, 1935; McBrearty & Brooks, 2000; McClure, 1994; Scerri, 2013), but
624 detailed microwear data that confirms this hypothesis has only recently become available (Coppe,
625 2020; Rots, 2002a, 2002b; Taipale, 2020; Taipale & Rots, 2021; S. Tomasso, 2021; S. Tomasso
626 & Rots, 2018). At Maisières-Canal, tangs are rather consistent in the concept of shaping but not
627 in their dimensions (see Touzé, 2018, 2019). This suggests that the employment of simple metrics
628 in measuring standardisation easily produces results that contradict the qualitative impression of
629 consistency or standardisation that lithic assemblages can give. The functional data collected on
630 tanged tools from Maisières-Canal provides another important perspective. While the tangs may
631 appear a uniform technological solution, they reflect different strategies in stone tool hafting.
632 Tanged burins were hafted in antler handles (Rots, 2002a), and a hafting system that was in
633 principle similar can be proposed for tanged butchery knives (Taipale & Rots, 2021), whereas on
634 projectile points, the tang served the purpose of compensating for blank curvature when the
635 contact with a split shaft was on the lateral sides of the tang (Coppe, 2020; Taipale et al., 2017).
636 Typo-technological similarity of non-active tool parts can thereby be coupled with diversity in
637 overall tool design, and conceptual standardisation of the former may imply diversification of the
638 latter.

639 Backing, i.e. the application of abrupt retouch on one edge of a lithic tool, is an assemblage feature
640 that is frequently associated with microlithic technologies that produce forms perceived as
641 standardised. Clarkson and colleagues have demonstrated through mechanical testing that
642 backing makes a lithic implement more resistant to fracture by bending. This is because it
643 produces artefacts that are relatively thick compared to their width, unlike their non-backed
644 counterparts (Clarkson et al., 2018). Backing can also straighten and regularise the edge opposite
645 to the cutting edge on a projectile point and aid reaching the desired characteristics of the entire
646 weapon when its different components are fitted together (e.g. Montoya, 2002). Even though the
647 link between backed artefacts and hafting is confirmed by the rare preservation of composite
648 points from late Upper Palaeolithic and younger contexts (see e.g. Nuzhnyj, 1989; Pétillon et al.,

649 2011 and references therein), the details of how backing interacts with different hafted tool
650 designs remain poorly understood.

651 In Gravettian projectile armatures, two main categories of backed tools can be distinguished:
652 Gravette and microgravette points, and truncated or snapped backed elements with non-pointed
653 extremities. Experimental testing and archaeological analysis have shown that Gravettes and
654 microgravettes can be and were used as distally hafted weapon tips (Cattelain & Perpère, 1993;
655 Coppe, 2020; Coppe & Rots, 2017; O'Farrell, 1996, 2004; Soriano, 1998; Taipale et al., 2022), in
656 addition to possible other functions (Harrold, 1993; Kimball, 1989; Perpère, 2000). The shaping
657 of the distal part of the points varies (e.g. Bricker, 1995; Cormarèche, 2020; Klaric et al., 2009;
658 Nespoulet, 1996; Touzé, 2019), but the characteristics of the typical proximal retouch on Gravette
659 points is assumed to relate to their hafting in one way or another (see e.g. Cattelain and Perpère,
660 1993; Coppe, 2020; O'Farrell, 1996, 2004; Soriano, 1998).

661 Based on the presently available experimental and archaeological data, the design of Gravette
662 points could be explained as combining two pragmatic solutions, one to mitigate the risk of
663 breakage in projectile use (cf. Clarkson et al., 2018) and the other to facilitate hafting. If both
664 correspond to functional demands or constraints, these two design features could theoretically
665 have been discovered by individual learning through the processes of trial and error, and in
666 Chase's (1991) terms, the Gravette point would not be a strong candidate for a mental template
667 communicated between individuals, as its constrained shape can be explained by factors related
668 to its use. Yet the geographical and temporal range of this tool type certainly demonstrate social
669 transmission of knowledge. This shows that a morphological type can simultaneously respond to
670 functional demands *and* be communicated as a concept between individuals and groups.

671 At Abri Pataud, the intentionally snapped and/or truncated Final Gravettian backed pieces
672 represent a 'standardised' tool category in that they are always backed and have a more or less
673 rectangular outline (see Chiotti et al., 2013; Clay, 1995). They were used as laterally hafted insets
674 in composite points (Taipale et al., 2022). Whereas increased resistance to bending breaks
675 achieved by backing (Clarkson et al., 2018) can be considered relevant for distally hafted Gravette
676 and microgravette points, the situation is different for composite points, where the organic body
677 of the point will primarily receive the bending stress on impact and where the effect of failure of
678 an individual lithic inset can be considered different to that on flint-tipped projectiles. The southern
679 African MSA and the Scandinavian Mesolithic records demonstrate that unretouched flakes and
680 fragments were successfully hafted as composite point insets (de la Peña et al., 2018; Knutsson
681 et al., 2016) and show that backing is not a functional obligation. It therefore requires additional
682 explanations.

An analysis of the backed pieces from the 1950s and 1960s Movius excavations at Abri Pataud found that nearly 90% of the widths of the backed bladelets centre around 6mm, suggesting that backing may have been a way to control width (Kong-Cho, 1997, p. 257). Material from the recent excavations that employed fine sieving, however, shows that the widths of the backed pieces dominantly range from 1 to 6mm, with outliers reaching 11mm (Chiotti et al., 2013, fig. 60; see also Guillermin, 2011, fig. 4) and were not as standardised as the Movius collection would suggest. Nevertheless, wish to control bladelet width should be maintained as a possible explanation, as bladelets of variable but predetermined width may have helped achieve desired alignment of the cutting edge when several insets were combined (cf. Pétillon et al., 2011).

The degree to which a back facilitates hafting of small lithics remains to be determined through further experiments. A recent preliminary test reported by Pargeter et al. concluded that backing worsens the adhesion of backed lithics instead of improving it (Pargeter et al., 2022). The experimental set-up and reporting of this study, however, contain several weaknesses. The experiment compared segments with curved backs to non-backed lithics with relatively straight edges. The backed pieces were also larger than the non-backed ones, which the authors justified by saying that thin pieces are difficult to back, a statement that can easily be contradicted by measurement data on archaeological backed lithics (e.g. Chiotti et al., 2013, fig. 60). The quantity of glue used, its extension onto the surfaces vs the back of the lithic, and the length of contact surface were also not reported. The projectiles were shot against a wooden board, meaning that the detachment of the lateral elements happened by shock rather than shearing, a situation that is only partly comparable to prehistoric hunting. The results of the study are therefore inconclusive, and further adhesion tests can be recommended.

Amongst actualistic projectile experiments, several tests have reported frequent detachment of laterally hafted backed elements from their shafts on impact (Chesnaux, 2014; Crombé et al., 2001; Moss & Newcomer, 1982; O'Farrell, 1996; Pétillon et al., 2011). This, however, is not proof enough that a back is useless or counterproductive for hafting, or designed for intentional hafting failure (cf. Pargeter et al., 2022). On the contrary, it highlights our limited understanding of glue properties and their range of variation (Tydgadt & Rots, 2022). The heavy use damage on the laterally hafted backed bladelets from Abri Pataud (Taipale et al., 2022) demonstrates that prehistoric artisans were able to apply adhesive in a manner that made the insets stay attached to the organic point on projectile impact. Future experiments addressing the usefulness of design features such as retouched backs should therefore aim at the replication of archaeologically documented damage patterns on lithic artefacts before attempting to draw conclusions about the functional significance of different retouch types.

## Discussion

### *Tool use, hafting, and the concept of standardisation*

The origins of the concept of 'standardisation' are tied to the debate about whether stone tool forms reflect socially shared (and possibly verbally communicated) 'mental templates' (see above). Many of the weaknesses in the attempts to implement this originally impressionistic and less-than-precisely defined concept in lithic analysis are linked to the analysts' need to take a side in this debate. To exaggerate somewhat, this has led to a situation where standardisation is perceived either as an intentional but arbitrary addition to stone tool form ('standardisation by desire'), or as a by-product of constraints imposed by raw material availability, technological strategies and skill, and/or functional constraints on tool form, and thereby in itself uninformative of past linguistic or cultural abilities ('standardisation by necessity'). We argue that insisting on this division masks any benefits that aspects of what is currently perceived as 'standardisation' could have for lithic analysts interested in the interactions between raw material economy, tool use, hafting, and blank production and shaping sequences. There is no reason to suspect that tool forms perfected through trial and error to match task-specific demands would not exist in the minds of tool makers in one form or another, or that knowledge about them would not be shared within the community by the available means of communication.

The value of the concept of 'standardisation' depends on which aspects of lithic assemblage variability it manages to capture and how these relate to past human behaviour. We have shown above that all tool use tasks are not equal in the way in which they control shape, which implies that the explicitness of patterning in working edge shapes and angles as well as the properties of the non-active parts of the tools are dependent on the activity range at a site. Resharpening modifies edge morphology, and differential phases of discard with respect to the degree and successfulness of resharpening can produce variable morphologies within a functionally uniform tool category, as shown by the example of hide scrapers from Verberie and some of the butchering knives from Maisières-Canal. Attempts to detect and explain morphological patterning in lithic assemblages would therefore greatly benefit from detailed functional data.

For hafting, we examined three variables that previous studies have used as measures of standardisation: blank selection (here, blades vs flakes), tool metrics, and retouch patterns. The first investigation showed that at Maisières-Canal, hafted tool technologies and blade production were connected, and the hafting of knives, projectiles, and hide-working tools seems to have driven the blade-dominated industry. Nevertheless, abundant hand-held burins made on blades demonstrate that there were incentives beyond hafting to opt for blades as tool blanks. These include the benefits of elongated blanks for the shaping and maintenance of burins that count

amongst dominant Upper Palaeolithic tool forms. The Abri Pataud case study, on the other hand, showed that haft designs existed that accommodated hide scrapers made on flakes, and that these were used in contexts where production and hafting of blade tools were well known. From the data accumulated on stone tool hafting thus far, it is evident that hafting predates blade-based industries, and that Upper Palaeolithic assemblages include both hafted flake tools and hand-held blade tools. This means that while blades are well-suited for certain forms of hafting, they represent only one solution amongst many. Therefore, the link between blades and hafted tool or composite tool technologies is not a simple one and necessitates further study, including the investigation of other motives to opt for blades.

Through measurement of basic tool dimensions, we could show that hafting of hide scraping tools may set a maximum limit to tool thickness. This means that metric control of blank variability may have been necessary in some tool use situations, and that investigating such regularities or standardisation in tool metrics could help understand choices made about blank production. While retooling is supposed to have a standardising effect on lithics (Kuhn & Shimelmitz, 2022), our scraper example in addition shows that even if tools do not need to fit the same (or similar) handle, they may share a maximum value of thickness. This suggests that hafting needs to be considered to understand the driving forces behind lithic production sequences (debitage, blank selection, and tool shaping).

Our examination of hafting-related retouch yielded more mixed results. Secondary modifications on hafted hide scraping tools ranged from absent to ones unconnected to hafted scraper use to retouch clearly applied to control the width of the non-active part. Therefore, the investigation of retouch patterns with regard to hafting-related standardisation requires background data on possible flexible use and/or recycling as well as on the details of the hafting arrangement. To our knowledge, such an approach has not yet been attempted. To broaden the perspective to other stone tool categories, even the most obvious hafting-related secondary modifications such as tangs and backing are yet to be fully understood in terms of the range of functional constraints and opportunities to which they responded.

Finally, the study of standardisation is complicated by variability linked to tool forms and knapping skill. Clarkson et al.'s experimental work has shown that certain tool forms (e.g. blade-based microliths) are more straightforward to copy by novice and intermediate knappers than others (bifacial points) (Clarkson et al., 2018), which implies that certain industries are more prone to appear as containing standardised artefacts than others simply due to higher levels of accurate copying. It is noteworthy that some of these artefacts, such as microlithic armatures, are relatively disposable compared to e.g. hide scrapers or butchering knives that can have lengthy use-lives (Odell, 1980; Shott & Weedman, 2007; Taipale, 2020; Taipale & Rots, 2021; Weedman, 2006).

787 The former therefore enter the archaeological record in much higher frequencies than the latter
788 and may also preserve their original morphology more often. Composite designs that combine
789 multiple small lithic insets into a single active edge further increase the number of discarded items
790 at sites where retooling took place. Together, these factors can contribute to the perceived
791 repetition of form simply due to discrepancy in absolute numbers and the relative length of
792 functional lives. This calls for a critical mindset in choosing tool classes to be compared in terms
793 of standardisation, and avoidance of overarching conclusions about broad-scale temporal and
794 regional differences in tool standardisation until factors such as tool function, length of use-lives,
795 and the skill involved in lithic production can be sufficiently accounted for.

796 Following these observations, we believe that employing the concept of 'standardisation' to the
797 benefit of our understanding of lithic assemblages and their behavioural implications necessitates
798 the concept to be updated so that it better responds to present-day research questions and
799 acknowledges the multiple variables controlling lithic technology. This is in line with other recent
800 calls to draw attention to behaviours such as retooling in attempts to explain large-scale patterns
801 in the lithic record (Kuhn & Shimelmitz, 2022).

802

803 ***How to address or test for standardisation?***

804 The discussion above reflects the trouble of defining 'standardisation' as a generalised concept
805 and applying it in lithic analysis. By contrast, standardisation of tool components and
806 morphological features seems to be present in different forms throughout the Palaeolithic. We
807 assert that the future value of the concept lies in detecting and demonstrating these kinds of
808 regularities in lithic assemblages.

809 To achieve good results, we propose an approach that employs functional data to 1) select
810 suitable groups of tools for analysis by focusing the attention to tools with the same function and
811 similar resharpening status, 2) differentiate between active and non-active tool parts, and 3)
812 reconstruct tool hafting and use in detail to identify relevant metric and qualitative attributes to
813 examine.

814 While suitable for an initial assessment of the relationship between domestic tool attributes and
815 hafting, the variables we included in the above analysis (blank type, basic measurements, position
816 of retouch) are evidently not enough to characterise the morphology of the tools in full detail. The
817 comparison of blank types provided promising initial results, but should be complemented with
818 controls for shape (e.g. elongation) to address potential overlap between blades and flakes. The
819 question whether retouch patterns are helpful in characterising hafted lithics is a more
820 complicated one. Our results on three Upper Palaeolithic assemblages indicate that hafting of

domestic tools does not always necessitate secondary modifications, and flexible use and recycling interfere with retouch patterns (Taipale, 2020). Similarly, our discussion of Middle and Upper Palaeolithic butchering knives above shows that the same active edge shape can be achieved by different debitage and secondary modification strategies. To employ measures of retouch in addressing standardisation, the particularities of each lithic industry need to be understood in detail.

Measuring is a fast and straightforward way to generate data on large samples of stone tools and therefore appeals to many archaeologists. However, the literature cited in the previous sections shows that metric standardisation may be elusive in the lithic record (see, however, Buchanan et al., 2018; Kuhn & Shimelmitz, 2022). Our discussion of Gravette points and Early Gravettian tanged tools above implies that what is qualitatively observed as standardisation (i.e. typo-technological markers) translates poorly into measurement data unless unnecessarily complex metrics are applied. Our analysis of hide scraper metrics showed that overall dimensions can reflect patterning related to hafting, but it is evident that in cases where the location of haft limit can be determined (see Rots et al., 2006; Taipale, 2020 for a critical discussion on locating the haft limit based on wear traces), measurements taken at this point would be a more reliable indicator of the constraints of the hafting system than maximum dimensions. We therefore believe that a re-evaluation of the usefulness of different metric attributes is in order and should exploit available functional data.

Ideally, this kind of analysis could be informative of the potential standardisation of and the probable variability in hafted tool designs in archaeological contexts where organic handles and shafts have not preserved. A functional approach shifts the attention to the design of complete hafted tools, a perspective that can be considered more fruitful for understanding the technical (and perhaps cognitive) competence of prehistoric human populations (cf. e.g. Barham, 2013) than a sole focus on stone tool forms. This viewpoint is becoming increasingly incorporated in studies on stone tool standardisation (Kuhn & Shimelmitz, 2022).

We thus call for closer interaction between functional analysts and researchers interested in morphometrics and quantification. Such collaboration may lead to new, useful insights into the meaning of stone tool variability.

## Conclusion

We have shown that standardisation is an ambiguously defined concept and that searching for standardisation in archaeological assemblages requires the integration of a functional perspective so that meaningful data can be obtained. Tool use sets specific demands on tool morphology and

855 constrains variability. We have argued that certain tool uses more easily lead to shared
856 morphological features of active edges across assemblages than others. Continued resharpening
857 determines how active edges evolve throughout their use cycle and variably affects the shape in
858 which tools are discarded. Not taking tool use into account therefore puts limits to any examination
859 of standardisation.

860 When hafting has been considered in studies on tool morphology, it has generally been assumed
861 to reduce morphological variation and to increase standardisation. This idea stems from the
862 premise that hafting would be a strategy that is rather generally applied once the expertise is
863 available. We have argued previously that the choice to haft a tool is more variable and depends
864 on e.g. site function and task frequency. Here, we have shown that even when hafting is widely
865 applied, it does not necessarily have a clear standardising effect on lithics. Morphological
866 variation does not decrease when a range of hafting systems is available and/or when one system
867 is flexible enough to accommodate lithic components of different size and/or shape. Our metric
868 data indicates that while the thickness of hafted tools may have an upper limit, the difference to
869 hand-held tools is not necessarily strong enough to lead to clear assemblage level patterning.
870 Retouch patterns on hafted tools are likewise variable, ranging from absence of retouch to clear
871 efforts to control blank shape and width. The initial variability we have observed calls for further
872 detailed functional studies to better connect morphometric variability and retouch strategies to
873 particular hafting arrangements.

874 The question of the relationship between blades and hafting has often been provoked and is an
875 intriguing one particularly in the light of high variability and partial absence of hafting-related
876 retouch in our present samples. We propose that blade production was not driven solely by the
877 need to haft certain stone tools but was also encouraged by other functional considerations. As
878 each stone tool formed a part of a larger toolkit, lithic *chaînes opératoires* served the purposes of
879 the entire kit by balancing the demands posed by each tool category and by exploiting
880 opportunities provided by the choices made.

881 We conclude that the inclusion of hafting trace data forces us to think about the complete tool
882 instead of just its replaceable stone component(s). This is a perspective that is currently being
883 brought into studies on standardisation, and we believe it is a key for such considerations. We
884 have shown here that standardised tool designs, such as composite points, may involve carefully
885 crafted and regularised stone insets as well as informal, non-standardised lithics. Future research
886 should therefore be geared towards understanding how different lithic shapes correspond to and
887 are controlled by demands related to task mechanics and hafting solutions, and how raw material
888 constraints interfered with past technical choices. In this research context, the concept
889 standardisation can help detect and describe regularities in tool form and contribute to an

890 improved understanding of lithic technological strategies. Finally, we encourage more interaction
891 between functional analysts and experts in morphometric approaches to fully understand the
892 variability in stone tool morphologies and their meaning.

893

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901

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916

917 ## Disclosure statement

918 The authors report there are no competing interests to declare.

919

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## References

Akerman, K. (1978). Notes on the Kimberley stone-tipped spear focusing on the point hafting mechanism. *Mankind*, *11*, 486–489.

Akerman, K., Fullagar, R., & van Gijn, A. (2002). Weapons and wunan: production, function and exchange of spear points from the Kimberley, Northwestern Australia. *Australian Aboriginal Studies*, *2002/1*, 13–42.

Antoine, P., Auguste, P., Munaut, A.-V., Frechen, M., Englemann, A., & Michel, V. (2002). Etudes géologiques, environnementales et datations. In J.-L. Locht (Ed.), *Bettencourt-Saint-Ouen (Somme), cinq occupations paléolithiques au début de la dernière glaciation* (pp. 15–55). Éditions de la Maison des sciences de l'homme.

Archer, W., & Braun, D. R. (2010). Variability in bifacial technology at Elandsfontein, Western cape, South Africa: a geometric morphometric approach. *Journal of Archaeological Science*, *37*(1), 201–209. https://doi.org/10.1016/j.jas.2009.09.033

Bar-Yosef, O., & Kuhn, S. L. (1999). The Big Deal about Blades: Laminar Technologies and Human Evolution. *American Anthropologist*, *101*(2), 322–338.

Barham, L. (2013). *From Hand to Handle: The First Industrial Revolution*. Oxford University Press.

Binford, L. R. (1973). Interassemblage Variability--The Mousterian and the "Functional" Argument. In *The Explanation of Culture Change: Models in Prehistory* (pp. 277–254). https://doi.org/10.2307/3103300

Binford, L. R., & Binford, S. R. (1966). A Preliminary Analysis of Functional Variability in the Mousterian Facies of Levallois. *American Anthropologist*, *68*(2), 238–295. https://doi.org/10.1525/aa.1966.68.2.02a001030

Bisson, M. S. (2001). Interview with a Neanderthal: An experimental approach for reconstructing scraper production rules, and their implications for imposed form in Middle Palaeolithic tools. *Cambridge Archaeological Journal*, *11*(2), 165–184. https://doi.org/10.1017/S0959774301000099

Bleed, P. (1986). The Optimal Design of Hunting Weapons: Maintainability or Reliability. *American Antiquity*, *51*(4), 737–747.

Bordes, F. (1953). Essai de Classification des industries "moustériennes." *Bulletin de La Société Préhistorique de France*, *50*(7–8), 457–466.

Bordes, F. (1967). Considérations sur la typologie et les techniques dans le Paléolithique. *Quartär*, *18*, 25–55.

Bordes, F. (1981). Vingt-cinq ans après : le complexe moustérien revisité. *Bulletin de La Société Préhistorique Française*, *78*(3), 77–87.

Bordes, F., & de Sonneville-Bordes, D. (1970). The significance of variability in Palaeolithic assemblages. *World Archaeology*, *2*(1), 61–73. https://doi.org/10.1080/00438243.1970.9979464

Bordes, F., Rigaud, J.-P., & de Sonneville-Bordes, D. (1972). Des buts, problèmes et limites de l'archéologie paléolithique. *Quaternaria*, *16*, 15–34.

Bricker, H. M. (1995). *Le paléolithique supérieur de l'abri Pataud (Dordogne): les fouilles de H. L. Movius Jr.* Éditions de la Maison des Sciences de l'Homme.

Bricker, H. M., & David, N. (1984). *Excavation of the Abri Pataud, Les Eyzies (Dordogne): The Périgordian VI (Level 3) Assemblage*. Peabody Museum of Archaeology and Ethnology.

Bricker, H. M., & David, N. (1995). Le Périgordian VI de l'abri Pataud niveau 3. In H. M. Bricker (Ed.), *Le Paléolithique supérieur de l'abri Pataud (Dordogne) : les fouilles de H. L. Movius Jr.* (pp. 89–104). Éditions de la Maison des Sciences de l'Homme.

Buchanan, B., Andrews, B., O'Brien, M. J., & Eren, M. I. (2018). An assessment of stone weapon tip standardization during the Clovis-Folsom transition in the western United States. *American Antiquity*, *83*(4), 721–734. https://doi.org/10.1017/aaq.2018.53

Buisson, D. (1991). Le Périgordien du Blot (Cerzat, Haute-Loire) [Note préliminaire]. *Bulletin de La Société Préhistorique Française*, *88*(4), 104–108. https://doi.org/10.3406/bspf.1991.9465

Callahan, E., Forsberg, L., Knutsson, K., & Lindgren, C. (1992). Frakturbilder. Kulturhistoriska kommentarer till det säregna sönderfallet vid bearbetning av kvarts. *Tor*, *24*, 27–63.

Cattelain, P. (1997). Hunting during the Upper Paleolithic: Bow, Spearthrower, or Both? In H. Knecht (Ed.), *Projectile Technology* (pp. 213–240). Plenum Press. https://doi.org/10.1007/978-1-4899-1851-2

Cattelain, P., & Perpère, M. (1993). Tir expérimental de sagaies et de flèches emmanchées de pointes de la Gravette. *Archéo-Situla*, *17–20*, 5–28.

Chase, P. G. (1991). Symbols and Paleolithic artifacts: Style, standardization, and the imposition of arbitrary form. *Journal of Anthropological Archaeology*, *10*(3), 193–214. https://doi.org/10.1016/0278-4165(91)90013-N

Chazan, M. (1995). The Language Hypothesis for the Middle-to-Upper Paleolithic Transition: An Examination Based on a Multiregional Lithic Analysis. *Current Anthropology*, *36*(5), 749–768.

Chesnaux, L. (2014). *Réflexion sur le microlithisme en France au cours du premier Mésolithique Xe-VIIIe millénaires avant J.-C.: approches technologique, expérimentale et fonctionelle*. Université de Paris 1 Panthéon-Sorbonne.

Chiotti, L., Nespoulet, R., & Henry-Gambier, D. (2015). Occupations and status of the Abri Pataud (Dordogne, France) during the Final Gravettian. *Quaternary International*, *359*, 406–422. https://doi.org/10.1016/j.quaint.2014.08.060

Chiotti, L., Nespoulet, R., Morala, A., & Guillermin, P. (2013). Données typo-technologiques de l'industrie lithique. In R. Nespoulet, L. Chiotti, & D. Henry-Gambier (Eds.), *Le Gravettien final de l'abri Pataud (Dordogne, France) : Fouilles et études 2005-2009. BAR International Series 2458* (pp. 111–126). Archaeopress.

Clark, J. D. (1970). *The prehistory of Africa*. Thames & Hudson.

Clark, J. E. (1987). Politics, Prismatic Blades, and Mesoamerican Civilization. In J. K. Johnson & C. A. Morrow (Eds.), *The Organization of Core Technology* (pp. 259–284). Westview Press.

Clarkson, C., Hiscock, P., Mackay, A., & Shipton, C. (2018). Small, Sharp, and Standardized: Global Convergence in Backed-Microlith Technology. In M. J. O'Brien, B. Buchanan, & M. I. Eren (Eds.), *Convergent Evolution in Stone-Tool Technology*. MIT Press.

Clay, R. B. (1995). Le Protomagdalénien de l'abri Pataud niveau 2. In H. M. Bricker (Ed.), *Le Paléolithique supérieur de l'abri Pataud (Dordogne) : les fouilles de H. L. Movius Jr.* (pp. 67–87). Éditions de la Maison des Sciences de l'Homme.

Coppe, J. (2020). *Sur les traces de l'armement préhistorique : mise au point d'une méthode pour reconstruire les modes d'emmanchement et de propulsion des armatures lithiques par une approche expérimentale, mécanique et balistique*. Université de Liège.

Coppe, J., Lepers, C., Clarenne, V., Delaunois, E., Pirlot, M., & Rots, V. (2019). Ballistic Study Tackles Kinetic Energy Values of Palaeolithic Weaponry. *Archaeometry*, *61*(4), 933–956. https://doi.org/10.1111/arcm.12452

Coppe, J., Lepers, C., & Rots, V. (2022). Projectiles Under a New Angle: a Ballistic Analysis Provides an Important Building Block to Grasp Paleolithic Weapon Technology. *Journal of Archaeological Method and Theory*. https://doi.org/10.1007/s10816-022-09551-z

Coppe, J., & Rots, V. (2017). Focus on the target. The importance of a transparent fracture terminology for understanding projectile points and projecting modes. *Journal of Archaeological Science: Reports*, *12*, 109–123. https://doi.org/10.1016/j.jasrep.2017.01.010

Corbey, R., Jagich, A., Vaesen, K., & Collard, M. (2016). The Acheulean handaxe: More like a bird's song than a Beatles' tune? *Evolutionary Anthropology*, *25*(1), 6–19. https://doi.org/10.1002/evan.21467

Cormarèche, E. (2020). *Les comportements techniques au Gravettien récent. Réflexions sur la diversité de l'équipement cynégétique lithique*. Université Paris Nanterre.

Crombé, P., Perdaen, Y., Sergant, J., & Caspar, J. (2001). Wear Analysis on Early Mesolithic Microliths from the Verrebroek Site, East Flanders, Belgium. *Journal of Field Archaeology*, *28*(3–4), 253–269. https://doi.org/10.1179/jfa.2001.28.3-4.253

de Heinzelin, J. (1973). *L'industrie du site paléolithique de Maisières-Canal*. Institut royal des sciences naturelles de Belgique.

de la Peña, P., Taipale, N., Wadley, L., & Rots, V. (2018). A techno-functional perspective on quartz micro-notches in Sibudu's Howiesons Poort reveals the use of barbs in hunting technology. *Journal of Archaeological Science*, *93*, 166–195. https://doi.org/10.1016/j.jas.2018.03.001

de Lombera-Hermida, A., & Rodríguez-Rellán, C. (2016). Quartzes matter. Understanding the technological and behavioural complexity in quartz lithic assemblages. *Quaternary International*, *424*, 2–11. https://doi.org/10.1016/j.quaint.2016.11.039

de Lombera Hermida, A. (2009). The scar identification of lithic quartz industries. In F. Sternke, L. Eigeland, & L.-J. Costa (Eds.), *Non-flint Raw Material Use in Prehistory. Old Prejudices and New Directions, BAR International Series 1939* (pp. 5–12).

Dibble, H. L. (1984). Interpreting Typological Variation of Middle Paleolithic Scrapers: Function, Style, or Sequence of Reduction? *Journal of Field Archaeology*, *11*(4), 431–436.

Dibble, H. L. (1987). The Interpretation of Middle Paleolithic Scraper Morphology. *American Antiquity*, *52*(1), 109–117. http://www.jstor.org/stable/281062

Dibble, H. L. (1989). The implications of stone tool types for the presence of language during the Lower and Middle Paleolithic. In P. Mellars & C. Stringer (Eds.), *The Human Revolution: Behavioural and Biological Perspectives on the Origins of Modern Humans* (pp. 415–432). Edinburgh University Press.

Dibble, H. L. (1991). Mousterian Assemblage Variability on an Interregional Scale. *Journal of Anthropological Research*, *47*(2), 239–257.

Dibble, H. L. (1995). Middle Palaeolithic scraper reduction: background, clarification, and review of evidence to date. *Journal of Archaeological Method and Theory*, *2*(4), 299–368.

1046 Domanski, M., Webb, J., & Boland, J. (1994). Mechanical Properties of Stone Artefact Materials and the
1047 Effect of Heat Treatment. *Archaeometry*, *36*(2), 177–208.
1048 http://onlinelibrary.wiley.com/doi/10.1111/j.1475-4754.1994.tb00963.x/abstract

1049 Douka, K., Chiotti, L., Nespoulet, R., & Higham, T. (2020). A refined chronology for the Gravettian sequence
1050 of Abri Pataud. *Journal of Human Evolution*, *141*, 102730.
1051 https://doi.org/10.1016/j.jhevol.2019.102730

1052 Driscoll, K. (2010). *Understanding quartz technology in early prehistoric Ireland* (Vol. 1, Issue January).
1053 University College Dublin.

1054 Driscoll, K. (2011a). Identifying and classifying vein quartz artefacts: An experiment conducted at the World
1055 Archaeological Congress, 2008. *Archaeometry*, *53*(6), 1280–1296. https://doi.org/10.1111/j.1475-
1056 4754.2011.00600.x

1057 Driscoll, K. (2011b). Vein quartz in lithic traditions: An analysis based on experimental archaeology. *Journal*
1058 *of Archaeological Science*, *38*(3), 734–745. https://doi.org/10.1016/j.jas.2010.10.027

1059 Ellis, C. J. (1997). Factors influencing the use of stone projectile tips: an ethnographic perspective. In H.
1060 Knecht (Ed.), *Projectile Technology* (pp. 37–78). Plenum Press.

1061 Enloe, J. G., & Audouze, F. (2010). The Magdalenian site of Verberie (Le Buisson Campin): An overview.
1062 In E. Zubrow, F. Audouze, & J. G. Enloe (Eds.), *The Magdalenian Household: Unraveling Domesticity*
1063 (pp. 15–21). State University of New York Press.

1064 Finlay, N. (2008). Blank concerns: Issues of skill and consistency in the replication of Scottish later
1065 Mesolithic blades. *Journal of Archaeological Method and Theory*, *15*(1), 68–90.
1066 https://doi.org/10.1007/s10816-007-9048-y

1067 Friis-Hansen, J. (1990). Mesolithic cutting arrows: functional analysis of arrows used in the hunting of large
1068 game. *Antiquity*, *64*, 494–504.

1069 Frison, G. C. (1968). A Functional Analysis of Certain Chipped Stone Tools. *American Antiquity*, *33*(2),
1070 149–155.

1071 Gaillard, Y., Chesnaux, L., Girard, M., Burr, A., Darque-Ceretti, E., Felder, E., Mazuy, A., & Regert, M.
1072 (2015). Assessing Hafting Adhesive Efficiency in the Experimental Shooting of Projectile Points: A
1073 new Device for Instrumented and Ballistic Experiments. *Archaeometry*, *58*(3), 465–483.
1074 https://doi.org/10.1111/arcm.12175

1075 Guillermin, P. (2011). La fin du Gravettien dans le sud-ouest de la France : à la recherche de l'identité
1076 protomagdalénienne…. In N. Goutas, L. Klaric, D. Pesesse, & P. Guillermin (Eds.), *À la recherche*
1077 *des identités gravettiennes : actualités, questionnements et perspectives. Actes de la table ronde sur*
1078 *le Gravettien en France et dans les pays limitrophes, Aix-en-Provence (6-8 octobre 2008) (Mémoire*
1079 *LII de la Société préhistorique françai* (pp. 129–144). Société préhistorique française.

1080 Guipert, G., de Lumley, M. A., Tuffreau, A., & Mafart, B. (2011). A late Middle Pleistocene hominid: Biache-
1081 Saint-Vaast 2, North France. *Comptes Rendus Palevol*, *10*(1), 21–33.
1082 https://doi.org/10.1016/j.crpv.2010.10.006

1083 Haesaerts, P., & Damblon, F. (2004). Les dates radiocarbone de Maisières-Canal. In R. Miller, P.
1084 Haesaerts, & M. Otte (Eds.), *L'atelier de taille aurigacien de Maisières-Canal (Belgique). ERAUL 110*
1085 (pp. 27–28). Études et Recherches Archéologiques de l'Université de Liège.

1086 Harrold, F. B. (1993). Variability and Function among Gravette Points from Southwestern France.
1087 *Archeological Papers of the American Anthropological Association*, *4*(1), 69–81.
1088 https://doi.org/10.1525/ap3a.1993.4.1.69

1089 Hiscock, P., Clarkson, C., & Mackay, A. (2011). Big debates over little tools: Ongoing disputes over
1090 microliths on three continents. *World Archaeology*, *43*(4), 653–664.

https://doi.org/10.1080/00438243.2011.624755

Hoggard, C. S., McNabb, J., & Cole, J. N. (2019). The Application of Elliptic Fourier Analysis in Understanding Biface Shape and Symmetry Through the British Acheulean. *Journal of Paleolithic Archaeology*, *2*(2), 115–133. https://doi.org/10.1007/s41982-019-00024-6

Holloway, R. L. (1969). Culture: A Human Domain. *Current Anthropology*, *10*(4), 395–412.

Iovita, R. (2011). Shape variation in Aterian tanged tools and the origins of projectile technology: A morphometric perspective on stone tool function. *PLoS ONE*, *6*(12), e29029. https://doi.org/10.1371/journal.pone.0029029

Iovita, R., & McPherron, S. P. (2011). The handaxe reloaded: A morphometric reassessment of Acheulian and Middle Paleolithic handaxes. *Journal of Human Evolution*, *61*(1), 61–74. https://doi.org/10.1016/j.jhevol.2011.02.007

Jacobi, R. M., Higham, T. F. G., Haesaerts, P., Jadin, I., & Basell, L. S. (2010). Radiocarbon chronology for the Early Gravettian of northern Europe: new AMS determinations for Maisières-Canal, Belgium. *Antiquity*, *84*(July), 26–40. https://doi.org/10.1017/S0003598X00099749

Jardón Giner, P., & Sacchi, D. (1994). Traces d'usage et indices de réaffûtages et d'emmanchements sur des grattoirs magdaleniens de la Grotte Gazel à Sallèles-Cabardes (Aude, France). *L'Anthropologie*, *98*(2–3), 427–446.

Jones, S. C., & Stewart, B. A. (2016). Africa from MIS 6-2: Population dynamics and palaeoenvironments. In *South African Archaeological Bulletin*.

Kamminga, J. (1982). *Over the edge: functional analysis of Australian stone tools*. University of Queensland.

Kimball, L. R. (1989). *Planning and Functional Variability in the Upper Palaeolithic: Microwear Analysis of Upper Perigordian Tools from Le Flageolet I (Dordogne).* Northwestern University.

Klaric, L. (2006). Des armatures aux burins : des critères de distinction techniques et culturels à partir des productions lamellaires de quelques sites du gravettien moyen et récent (France). In M. de Araujo Igreja, J.-P. Bracco, & F. Le Brun-Ricalens (Eds.), *Burins prehistoriques : formes, fonctionnements, fonctions. Actes de la table-ronde d'Aix-en-Provence (3–5 mars 2003)* (pp. 199–223). Musée National d'Histoire et d'Art.

Klaric, L. (2018). *The prehistoric apprentice: Investigating apprenticeship, know-how and expertise in prehistoric technologies - L'apprenti préhistorique : Appréhender l'apprentissage, les savoir-faire et l'expertise à travers les productions techniques des sociétés préhistoriques*. The Czech Academy of Sciences, Institute of Archaeology.

Klaric, L., Guillermin, P., & Aubry, T. (2009). Des armatures variées et des modes de productions variables : Réflexions à partir de quelques exemples issus du Gravettien d'Europe occidentale (France, Portugal, Allemagne). *Gallia Préhistoire*, *51*, 113–154.

Knecht, H. (1997). *Projectile Technology*. Plenum Press.

Knutsson, H., Knutsson, K., Molin, F., & Zetterlund, P. (2016). From flint to quartz: Organization of lithic technology in relation to raw material availability during the pioneer process of Scandinavia. *Quaternary International*, *424*, 32–57. https://doi.org/10.1016/j.quaint.2015.10.062

Knutsson, H., Knutsson, K., Taipale, N., Tallavaara, M., & Darmark, K. (2015). How shattered flakes were used: Micro-wear analysis of quartz flake fragments. *Journal of Archaeological Science: Reports*, *2*, 517–531. https://doi.org/10.1016/j.jasrep.2015.04.008

Kohn, M., & Mithen, S. (1999). Handaxes: Products of sexual selection? *Antiquity*, *73*(281), 518–526. https://doi.org/10.1017/S0003598X00065078

Kong-Cho, S. (1997). *Étude de l'industrie lithique de la couche 2 dite protomagdalenienne de l'abri Pataud (Les Eyzies, Dorgodne) : etude technologique et typologique*. Museum National d'Histoire Naturelle.

Kuhn, S. L. (1992). Blank Form and Reduction as Determinants of Mousterian Scraper Morphology. *American Antiquity*, *57*(1), 115–128. https://doi.org/10.2307/2694838

Kuhn, S. L., & Shimelmitz, R. (2022). From Hafting to Retooling: Miniaturization as Tolerance Control in Paleolithic and Neolithic Blade Production. *Journal of Archaeological Method and Theory*. https://doi.org/10.1007/s10816-022-09575-5

Lassen, R., & Williams, T. (2015). Variation in flintknapping skill among Folsom-era projectile point types: A quantitative approach. *Journal of Archaeological Science: Reports*, *4*, 164–173. https://doi.org/10.1016/j.jasrep.2015.09.007

Lindgren, C. (1998). Shapes of quartz and shapes of minds. In L. Holm & K. Knutsson (Eds.), *Proceedings from the Third Flint Alternatives Conference at Uppsala, Sweden, October 18-20, 1996. Occasional Papers in Archaeology 16*. Department of Archaeology and Ancient History, Uppsala University.

Macdonald, D. A., Bartkowiak, T., & Stemp, W. J. (2020). 3D multiscale curvature analysis of tool edges as an indicator of cereal harvesting intensity. *Journal of Archaeological Science: Reports*, *33*(July), 102523. https://doi.org/10.1016/j.jasrep.2020.102523

Manninen, M. A. (2016). The effect of raw material properties on flake and flake-tool dimensions: A comparison between quartz and chert. *Quaternary International*. https://doi.org/10.1016/j.quaint.2015.12.096

Manninen, M. A., & Knutsson, K. (2011). Northern inland oblique point sites – a new look into the Late Mesolithic oblique point tradition in Eastern Fennoscandia. In T. Rankama (Ed.), *Mesolithic Interfaces. Variability in Lithic Technologies in Eastern Fennoscandia. Monographs of the Archaeological society of Finland* (Vol. 1, pp. 142–175). Archaeological Society of Finland.

Manninen, M. A., & Tallavaara, M. (2011). Descent History of Mesolithic Oblique Points in Eastern Fennoscandia – a Technological Comparison Between Two Artefact Populations. In T. Rankama (Ed.), *Mesolithic Interfaces. Variability in Lithic Technologies in Eastern Fennoscandia* (Vol. 1, pp. 176–211). Archaeological Society of Finland.

Marchand, H., & Aymé, A. (1935). Recherches stratigraphiques sur l'Atérien. *Bulletin de La Société d'Histoire Naturelle d'Afrique Du Nord*, *XXVI*.

Marks, A., Hietala, H. J., & Williams, J. K. (2001). Tool Standardization in the Middle and Upper Palaeolithic: a Closer Look (with comments). *Cambridge Archaeological Journal*, *11*(1), 17–44. https://doi.org/10.1017/s0959774301000026

McBrearty, S., & Brooks, A. S. (2000). The revolution that wasn't: A new interpretation of the origin of modern human behavior. *Journal of Human Evolution*, *39*(5), 453–563. https://doi.org/10.1006/jhev.2000.0435

McCall, G. S., & Thomas, J. T. (2012). Still Bay and Howiesons Poort Foraging Strategies: Recent Research and Models of Culture Change. *African Archaeological Review*, *29*(1), 7–50. https://doi.org/10.1007/s10437-012-9107-y

McClure, H. A. (1994). A new Arabian stone tool assemblage and notes on the Aterian industry of North Africa. *Arabian Archaeology and Epigraphy*, *5*(1), 1–16.

McNabb, J., Binyon, F., & Hazelwood, L. (2004). The Large Cutting Tools from the South African Acheulean and the Question of Social Traditions. *Current Anthropology*, *45*(5), 653–677.

Mellars, P. (1989). Major Issues in the Emergence of Modern Humans. *Current Anthropology*, *30*(3), 349–385. https://doi.org/10.1086/203755

Mellars, P. (1991). Cognitive Changes and the Emergence of Modern Humans in Europe. *Cambridge*

*Archaeological Journal*, *1*(1), 63–76. https://doi.org/10.1017/S0959774300000251

Mellars, P. (1996). *The Neanderthal Legacy: an Archaeological Perspective from Western Europe*. Princeton University Press.

Monnier, G. (2006). Testing Retouched Flake Tool Standardization During the Middle Paleolithic. In E. Hovers & S. L. Kuhn (Eds.), *Transitions Before the Transition* (pp. 57–83). Springer.

Montoya, C. (2002). Les pointes à dos épigravettiennes de Saint-Antoine-Vitrolles (Hautes-Alpes) : diversité typologique ou homogénéité conceptuelle ? *Bulletin de la Société préhistorique française, 99*(2): 275–287.

Moreau, L., Brandl, M., Filzmoser, P., Hauzenberger, C., Goemaere, É., Jadin, I., Collet, H., Hauzeur, A., & Schmitz, R. W. (2016). Geochemical Sourcing of Flint Artifacts from Western Belgium and the German Rhineland: Testing Hypotheses on Gravettian Period Mobility and Raw Material Economy. *Geoarchaeology*, *31*(3), 229–243. https://doi.org/10.1002/gea.21564

Moreau, L., Hauzeur, A., & Jadin, I. (2013). La gestion des ressources lithiques dans l'ensemble gravettien de Maisières-Canal (Bassin de Mons, Hainaut, B). Nouvelles perspectives. *Notae Praehistoricae*, *33*, 105–126.

Moss, E. H. (1983). Some comments on edge damage as a factor in functional analysis of stone artifacts. *Journal of Archaeological Science*, *10*(3), 231–242. https://doi.org/10.1016/0305-4403(83)90006-7

Moss, E. H., & Newcomer, M. H. (1982). Reconstruction of Tool Use at Pincevent: Microwear and Experiments. In *Tailler! Pourquoi faire: Préhistoire et technologie lithique II, Recent Progress in Microwear Studies. Studia Praehistorica Belgica Leuven 2* (pp. 289–312).

Mourre, V. (1996). Les industries en quartz au Paléolithique. Terminologie, méthodologie et technologie. *Paléo*, *8*(1), 205–223. https://doi.org/10.3406/pal.1996.1160

Movius, H. L. J. (1975). *Excavation of the Abri Pataud, Les Eyzies (Dordogne)*. Peabody Museum of Archaeology and Ethnology, Harvard University.

Movius, H. L. J. (1977). *Excavation of the Abri Pataud, Les Eyzies (Dordogne): Stratigraphy*. Peabody Museum of Archaeology and Ethnology, Harvard University.

Muller, A., Shipton, C., & Clarkson, C. (2022). Stone toolmaking difficulty and the evolution of hominin technological skills. *Scientific Reports*, *12*(1), 1–12. https://doi.org/10.1038/s41598-022-09914-2

Nelson, M. C. (1991). The Study of Technological Organization. *Archaeological Method and Theory*, *3*(1991), 57–100. https://doi.org/10.2307/20170213

Nespoulet, R. (1996). *Le Périgordien VI de l'abri Pataud, Les Eyzies-de-Tayac, Dordogne. L'étude technologique et typologique de l'industrie lithique de la couche 3*. Muséum national d'histoire naturelle.

Nespoulet, R. (2000). Le Gravettien final de l'abri Pataud, Les Eyzies-de-Tayac, Dordogne : Nouvelles données technologiques et typologiques sur l'industrie lithique provenant du niveau 3. *L'Anthropologie*, *104*, 63–120.

Nespoulet, R., Chiotti, L., & Henry-Gambier, D. (2013). *Le Gravettien final de l'abri Pataud (Dordogne, France) : Fouilles et études 2005-2009*. BAR International Series 2458, Archaeopress.

Nicoud, É. (2013). Complexité des stratigraphies régionales et nouveau modèle d'apparition et de diffusion du phénomène acheuléen en Europe de l'ouest. *Quaternaire*, *24*(4), 407–417. https://doi.org/10.4000/quaternaire.6790

Nonaka, T., Bril, B., & Rein, R. (2010). How do stone knappers predict and control the outcome of flaking? Implications for understanding early stone tool technology. *Journal of Human Evolution*, *59*(2), 155–167. https://doi.org/10.1016/j.jhevol.2010.04.006

Nuzhnyj, D. (1989). L'utilisation des microlithes géométriques et non géométriques comme armatures de projectiles. *Bulletin de La Société Préhistorique Française*, *86*(3), 88–96. https://doi.org/10.3406/bspf.1989.9368

O'Farrell, M. (1996). *Approche technologique et fonctionnelle des pointes de la Gravette : une analyse archéologique et expérimentale appliquée à la collection de Corbiac (Dordogne)*. Université de Bordeaux I.

O'Farrell, M. (2004). Les pointes de La Gravette de Corbiac (Dordogne) et considérations sur la chasse au Paléolithique supérieur ancien. In P. Bodu & C. Constantin (Eds.), *Approches fonctionnelles en préhistoire. Actes du XXVe Congrès Préhistorique de France, Nanterre 24-26 novembre 2000* (pp. 121–138). Société préhistorique française.

Odell, G. H. (1980). Butchering With Stone Tools: Some Experimental Results. *Lithic Technology*, *9*(2), 39–48. https://doi.org/10.1080/01977261.1980.11754469

Odell, G. H. (1981). The Morphological Express at Function Junction: Searching for Meaning in Lithic Tool Types. *Journal of Anthropological Research*, *37*(4), 319–342. https://doi.org/10.2307/3629831

Otte, M. (1979). Documentation archéologique. In P. Haesaerts & J. de Heinzelin (Eds.), *Le site paléolithique de Maisières-Canal*. De Tempel.

Pargeter, J., Chen, C., Buchanan, B., Fisch, M., Bebber, M., & Eren, M. I. (2022). Stone tool backing and adhesion in hunting weaponry: First results of an experimental program. *Journal of Archaeological Science: Reports*, *45*, 103639. https://doi.org/10.1016/j.jasrep.2022.103639

Pelegrin, J. (2021). Sur la motivation des tailleurs experts du Paléolithique supérieur. *Paléo*, *Hors-série*(Décembre 2021), 148–165. https://doi.org/10.4000/paleo.6895

Perpère, M. (2000). Les points de La Gravette de la couche 5 de l'abri Pataud : Réflexion sur les armes de pierre dans les outillages périgordiens. *Anthropologie et Préhistoire*, *111*, 19–27.

Pesesse, D., & Flas, D. (2012). The Maisierian, at the edge of the Gravettian. *Proceedings of the Prehistoric Society*, *78*, 95–109. https://doi.org/10.1017/S0079497X00027122

Pétillon, J.-M., Bignon, O., Bodu, P., Cattelain, P., Debout, G., Langlais, M., Laroulandie, V., Plisson, H., & Valentin, B. (2011). Hard core and cutting edge: Experimental manufacture and use of Magdalenian composite projectile tips. *Journal of Archaeological Science*, *38*(6), 1266–1283. https://doi.org/10.1016/j.jas.2011.01.002

Pigeot, N. (1987). *Magdaléniens d'Étiolles. Economie de débitage et organisation sociale (l'unité d'habitation U5) (XXVe supplément à Gallia Préhistoire)*. Éditions du CNRS.

Plisson, H. (2006). Un burin ne sert pas à buriner mais en burinant... In M. de Araujo Igreja, J.-P. Bracco, & F. Le Brun-Ricalens (Eds.), *Burins prehistoriques : formes, fonctionnements, fonctions. Actes de la table-ronde d'Aix-en-Provence (3–5 mars 2003)* (Vol. 2, pp. 23–33). Musée National d'Histoire et d'Art.

Plisson, H., & Beyries, S. (1998). Pointes ou outils triangulaires ? Données fonctionnelles dans le Moustérien levantin [suivi des] Commentaires de J. Shea, A. Marks, J-M Geneste et de la réponse des auteurs. *Paléorient*, *24*(1), 5–24. https://doi.org/10.3406/paleo.1998.4666

Rankama, T. (2002). Analyses of the quartz assemblages of houses 34 and 35 at Kauvonkangas in Tervola. In H. Ranta (Ed.), *Huts and Houses. Stone Age and Early Metal Age Buildings in Finland.* (pp. 79–108). National Board of Antiquities.

Rankama, T., Manninen, M. A., Hertell, E., & Tallavaara, M. (2006). Simple production and social strategies: do they meet? Social dimensions in Eastern Fennoscandian quartz technologies. In J. Apel & K. Knutsson (Eds.), *Skilled Production and Social Reproduction: Aspects of Traditional Stone-Tool Technologies. Proceedings of a Symposium in Uppsala, August 20-24, 2003* (pp. 245-). Societas Archaeologica Upsaliensis.

Rodríguez-Rellán, C. (2016). Variability of the rebound hardness as a proxy for detecting the levels of continuity and isotropy in archaeological quartz. *Quaternary International*, *424*, 191–211. https://doi.org/10.1016/j.quaint.2015.12.085

Rolland, N., & Dibble, H. L. (1990). A New Synthesis of Middle Paleolithic Variability. *American Antiquity*, *55*(3), 480–499.

Rots, V. (2002a). Are Tangs Morphological Adaptations in View of Hafting? Macro- and microscopic wear analysis on a selection of tanged burins from Maisières-Canal. *Notae Praehistoricae*, *22*, 61–69.

Rots, V. (2002b). *Hafting Traces on Flint Tools: Possibilities and Limitations of Macro- and Microscopic Approaches*. Katholieke Universiteit Leuven.

Rots, V. (2003). Towards an understanding of hafting. *Antiquity*, *77*, 805–815. https://doi.org/https://doi.org/10.1017/S0003598X00061743

Rots, V. (2005). Wear traces and the interpretation of stone tools. *Journal of Field Archaeology*, *30*(1), 61–73. https://doi.org/https://doi.org/10.1179/009346905791072404

Rots, V. (2009). The functional analysis of the Mousterian and Micoquian assemblages of Sesselfelsgrotte, Germany: aspects of tool use and hafting in the European Late Middle Palaeolithic. *Quartär*, *56*, 37–66. https://lirias.kuleuven.be/handle/123456789/230551

Rots, V. (2010). *Prehension and hafting traces on flint tools: a methodology*. Universitaire Pers Leuven.

Rots, V. (2013). Insights into early Middle Palaeolithic tool use and hafting in Western Europe. The functional analysis of level IIa of the early Middle Palaeolithic site of Biache-Saint-Vaast (France). *Journal of Archaeological Science*, *40*, 497–506. https://doi.org/https://doi.org/10.1016/j.jas.2012.06.042

Rots, V. (2015). Hafting and Site Function in the European Middle Paleolithic. In N. J. Conard & A. Delagnes (Eds.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age: Vol. IV* (pp. 383–410). Kerns Verlag.

Rots, V., Coppe, J., & Conard, N. J. (2021). A Leaf Point Documents Hunting with Spears in the Middle Paleolithic at Hohle Fels, Germany. *Mitteilungen Der Gesellschaft Für Urgeschichte*, *2021*(30), 1–28. https://doi.org/10.51315/mgfu.2021.30004

Rots, V., Hayes, E., Akerman, K., Green, P., Clarkson, C., Lepers, C., Bordes, L., McAdams, C., Foley, E., & Fullagar, R. (2020). Hafted Tool-use Experiments with Australian Aboriginal Plant Adhesives: Triodia Spinifex, Xanthorrhoea Grass Tree and Lechenaultia divaricata Mindrie. *EXARC Journal*, *2020/1*, 1–10.

Rots, V., Lentfer, C., Schmid, V. C., Porraz, G., & Conard, N. J. (2017). Pressure flaking to serrate bifacial points for the hunt during the MIS5 at Sibudu Cave (South Africa). *PLoS ONE*, *12*(4), e0175151. https://doi.org/10.1371/journal.pone.0175151

Rots, V., Pirnay, L., Pirson, P., & Baudoux O. (2006). Blind tests shed light on possibilities and limitations for identifying stone tool prehension and hafting. *Journal of Archaeological Science 33*(7), 935–952. https://doi.org/10.1016/j.jas.2005.10.018

Rots, V., & Plisson, H. (2014). Projectiles and the abuse of the use-wear method in a search for impact. *Journal of Archaeological Science*, *48*(1), 154–165. https://doi.org/10.1016/j.jas.2013.10.027

Rots, V., & Van Peer, P. (2006). Early evidence of complexity in lithic economy: Core-axe production, hafting and use at late Middle Pleistocene site 8-B-11, Sai Island (Sudan). *Journal of Archaeological Science*, *33*(3), 360–371. https://doi.org/10.1016/j.jas.2005.08.002

Rots, V., Van Peer, P., & Vermeersch, P. M. (2011). Aspects of tool production, use, and hafting in Palaeolithic assemblages from Northeast Africa. *Journal of Human Evolution*, *60*(5), 637–664. https://doi.org/10.1016/j.jhevol.2011.01.001

Rots, V., & Williamson, B. S. (2004). Microwear and residue analyses in perspective: The contribution of ethnoarchaeological evidence. *Journal of Archaeological Science*, *31*(9), 1287–1299. https://doi.org/10.1016/j.jas.2004.02.009

Scerri, E. M. L. (2013). On the spatial and technological organisation of hafting modifications in the North African Middle Stone Age. *Journal of Archaeological Science*, *40*(12), 4234–4248. https://doi.org/10.1016/j.jas.2013.06.011

Schlanger, N. (1996). Understanding Levallois: Lithic technology and cognitive archaeology. *Cambridge Archaeological Journal*, *6*(2), 231–254. https://doi.org/10.1017/s0959774300001724

Semenov, S. A. (1964). *Prehistoric Technology: An experimental study of the oldest tools and artefacts from traces of manufacture and wear*. Adams & Dart.

Shott, M. J., & Weedman, K. J. (2007). Measuring reduction in stone tools: an ethnoarchaeological study of Gamo hidescrapers from Ethiopia. *Journal of Archaeological Science*, *34*(7), 1016–1035. https://doi.org/10.1016/j.jas.2006.09.009

Soriano, S. (1998). Les microgravettes du Périgordien de Rabier à Lanquais (Dordogne) : analyse technologique fonctionnelle. *Gallia Préhistoire*, *40*(1), 75–94. https://doi.org/10.3406/galip.1998.2158

Soriano, S., Villa, P., Delagnes, A., Degano, I., Pollarolo, L., Lucejko, J. J., Henshilwood, C., & Wadley, L. (2015). The Still Bay and Howiesons Poort at Sibudu and Blombos: Understanding Middle Stone Age Technologies. *PloS One*, *10*(7), e0131127. https://doi.org/10.1371/journal.pone.0131127

Sternke, F., & Sørensen, M. (2009). The identification of children's flint knapping products in Mesolithic Scandinavia. In S. McCartan, R. Schulting, G. Warren, & P. Woodman (Eds.), *Mesolithic Horizons: Papers Presented at the Seventh International Conference on the Mesolithic in Europe, Belfast 2005* (pp. 720–729). Oxbow Books.

Stordeur, D. (1987). Manches et emmanchements préhistoriques : quelques propositions préliminaires. In D. Stordeur (Ed.), *La main et l'outil. Manches et emmanchements préhistoriques* (pp. 11–34). Maison de l'Orient Méditerranéen.

Taipale, N. (2020). *Hafting as a flexible strategy: variability in stone tool use and hafting at three European Upper Palaeolithic sites*. University of Liège.

Taipale, N., Chiotti, L., & Rots, V. (2022). Why did hunting weapon design change at Abri Pataud? Lithic use-wear data on armature use and hafting around 24,000–22,000 BP. *PLOS ONE*, *17*(1), e0262185. https://doi.org/10.1371/journal.pone.0262185

Taipale, N., Coppe, J., Touzé, O., & Rots, V. (2017). The weapon system behind the point: Early Gravettian hunting technologies at Maisières-Canal (published abstract). *PESHE 6*, 193. https://doi.org/10.1080/15228967.2011.556516

Taipale, N., & Rots, V. (2020). Revisiting Maisières-Canal (Hainaut, BE): New results on tool use and hafting. *Notae Praehistoricae*, *40*, 105–127.

Taipale, N., & Rots, V. (2021). Every hunter needs a knife: Hafted butchering knives from Maisières-Canal and their effect on lithic assemblage characteristics. *Journal of Archaeological Science: Reports*, *36*, 102874.

Tallavaara, M., Manninen, M. A., Hertell, E., & Rankama, T. (2010). How flakes shatter: A critical evaluation of quartz fracture analysis. *Journal of Archaeological Science*, *37*(10), 2442–2448. https://doi.org/10.1016/j.jas.2010.05.005

Tardy, N., Vosges, J., & Varoutsikos, B. (2016). Micro-blade production on hyaline quartz during the Late Neolithic of northern Greece (5400–4600 cal. B.C.): Examples from Dikili Tash and Promachonas-Topolniča. *Quaternary International*, *424*, 212–231. https://doi.org/10.1016/j.quaint.2015.11.139

Tomasso, A., Rots, V., Purdue, L., Beyries, S., Buckley, M., Cheval, C., Cnuts, D., Coppe, J., Julien, M. A.,

Grenet, M., Lepers, C., M'hamdi, M., Simon, P., Sorin, S., & Porraz, G. (2018). Gravettian weaponry: 23,500-year-old evidence of a composite barbed point from Les Prés de Laure (France). *Journal of Archaeological Science*, *100*, 158–175. https://doi.org/10.1016/j.jas.2018.05.003

Tomasso, S. (2021). *What is new in the Aterian? A functional view on tool use, hafted stone tool technologies and assemblage variability at Ifri n'Ammar within the context of the Northwest African Middle Stone Age*. University of Liège.

Tomasso, S., Cnuts, D., Mikdad, A., & Rots, V. (2020). Changes in hafting practices during the Middle Stone Age at Ifri n' Ammar. *Quaternary International*, *555*(March), 21–32. https://doi.org/10.1016/j.quaint.2020.03.026

Tomasso, S., & Rots, V. (2018). What is the use of shaping a tang? Tool use and hafting of tanged tools in the Aterian of Northern Africa. *Archaeological and Anthropological Sciences*, *10*(6), 1389–1417. https://doi.org/10.1007/s12520-016-0448-3

Touzé, O. (2018). Aux prémices du Gravettien dans le Nord-Ouest européen. Étude de la production des pointes lithiques à Maisières- Canal (province de Hainaut, Belgique). *Bulletin de La Société Préhistorique Française*, *115*(3), 455–495.

Touzé, O. (2019). *D'une tradition à l'autre, les débuts de la période gravettienne. Trajectoire technique des sociétés des chasseurs-cueilleurs d'Europe nord-occidentale*. Université de Liège / Université Paris 1 Panthéon-Sorbonne.

Tydgadt, L., & Rots, V. (2022). Stick to it! Mechanical performance tests to explore the resilience of prehistoric glues in hafting. *Archaeometry*, *January*, 1252–1269. https://doi.org/10.1111/arcm.12779

Villa, P., & Roebroeks, W. (2014). Neandertal Demise: An Archaeological Analysis of the Modern Human Superiority Complex. *PLoS ONE*, *9*(4), 1–10. https://doi.org/10.1371/journal.pone.0096424

Way, A. M., de la Peña, P, de la Peña, E., & Wadley, L. (2022). Howiesons Poort backed artifacts provide evidence for social connectivity across southern Africa during the Final Pleistocene. *Scientific Reports, 12*(1), 1–12. https://doi.org/10.1038/s41598-022-12677-5

Weedman, K. J. (2006). An ethnoarchaeological study of hafting and stone tool diversity among the gamo of Ethiopia. *Journal of Archaeological Method and Theory*, *13*(3), 188–237. https://doi.org/10.1007/s10816-006-9010-4

White, M. J. (1998). On the Significance of Acheulean Biface Variability in Southern Britain. *Proceedings of the Prehistoric Society*, *64*, 15–44. https://doi.org/10.1017/s0079497x00002164

Wierer, U. (2013). Variability and standardization: The early Gravettian lithic complex of Grotta Paglicci, Southern Italy. *Quaternary International*, *288*, 215–238. https://doi.org/10.1016/j.quaint.2012.04.043

Wynn, T. (1988). Tools and the evolution of human intelligence. In R. Byrne & A. Whiten (Eds.), *Machiavellian Intelligence: Social Expertise and the Evolution of Intellect in Monkeys, Apes, and Humans* (pp. 271–284). Oxford University Press.